LBNL- 1006983

Electricity end uses, energy efficiency, and distributed energy resources baseline: *Evaluation, Measurement, and Verification Appendix*

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January 2017

This work was supported by the Department of Energy, Office of Energy Policy and Systems Analysis, under Lawrence Berkeley National Laboratory Contract No. DE-AC02-05CH11231.

Acknowledgments

The authors thank the U.S. Department of Energy Office of Energy Policy and Systems Analysis (EPSA) for sponsoring and guiding this work, including John Agan, Erin Boyd, Natalie Kempkey, and Jenah Zweig. The authors also thank the following organizations that provided comments on the draft report: DOE's Office of Energy Efficiency and Renewable Energy (EERE), the Energy Information Administration (EIA), the Environmental Protection Agency (EPA), the National Association of Regulatory Utility Commissioners (NARUC), the National Association of State Energy Officials (NASEO), the Regulatory Assistance Project (RAP), and the American Council for an Energy-Efficient Economy (ACEEE).

In addition, the authors appreciate the peer reviewers who provided valuable input: *for the residential sector*, Craig Christensen and Eric Wilson, National Renewable Energy Laboratory (NREL), and Richard Faesy, Energy Futures Group; *for the commercial sector*, Michael Deru and Shanti Pless, NREL; *for the industrial sector*, Kelly Perl, Energy Information Administration, Diane Graziano and Danilo Santini, Argonne National Laboratory (ANL), and Keith Jamison, Energetics; *for the transportation sector*, John German, International Council on Clean Transportation and Danilo Santini, ANL; *for distributed energy resources*, Genevieve Saur and Ben Sigrin, NREL, and Peter Cappers, Lawrence Berkeley National Laboratory; and for *evaluation, measurement, and verification*, Jane Peters, Research Into Action, and Ralph Prahl, Ralph Prahl and Associates and Steve Kromer, Kromer Engineering. Finally, we are grateful for copy editing support by Mark Wilson.

Any remaining errors, omissions, or mischaracterizations are the responsibility of the authors.

Scope and Organization

This report was developed by a team of analysts at Lawrence Berkeley National Laboratory, with Argonne National Laboratory contributing the transportation section, and is a DOE EPSA product and part of a series of "baseline" reports intended to inform the second installment of the Quadrennial Energy Review (QER 1.2). QER 1.2 provides a comprehensive review of the nation's electricity system and cover the current state and key trends related to the electricity system, including generation, transmission, distribution, grid operations and planning, and end use. The baseline reports provide an overview of elements of the electricity system. This report focuses on end uses, electricity consumption, electric energy efficiency, distributed energy resources (DERs) (such as demand response, distributed generation, and distributed storage), and evaluation, measurement, and verification (EM&V) methods for energy efficiency and DERs.

Chapter 1 provides context for the report and an overview of electricity consumption across all market sectors, summarizes trends for energy efficiency and DERs and their impact on electricity sales, and highlights the benefits of these resources as well as barriers to their adoption. Lastly it summarizes policies, regulations, and programs that address these barriers, highlighting crosscutting approaches, from resource standards to programs for utility customers to performance contracting.

Chapters 2 through 5 characterize end uses, electricity consumption, and energy efficiency for the residential, commercial, and industrial sectors as well as electrification of the transportation sector. Chapter 6 addresses DERs—demand response, distributed generation, and distributed storage.

Several chapters in this report include appendices with additional supporting tables, figures, and technical detail. In addition, the appendix also includes a separate section that discusses current and evolving EM&V practices for energy efficiency and DERs, approaches for conducting reliable and cost-effective evaluation, and trends likely to affect future EM&V practices.

This excerpt is the Evaluation, Measurement, and Verification Appendix for the report. The full report is available at https://emp.lbl.gov/publications/electricity-end-uses-energy.

Description of Energy Models[a]

Unless otherwise noted, this report provides projections between the present-day and 2040 using the "EPSA Side Case," a scenario developed using a version of the Energy Information Administration's (EIA's) National Energy Modeling System (NEMS). Since the EPSA Side Case was needed for this and other EPSA baseline reports in advance of the completion of EIA's Annual Energy Outlook (AEO) 2016, it uses data from EIA's AEO 2015 Reference Case, the most recent AEO available at the time. However, since AEO 2015 did not include some significant policy and technology developments that occurred during 2015, the EPSA Side Case was designed to reflect these changes.

The EPSA Side Case scenario was constructed using EPSA-NEMs,[b] a version of the same integrated energy system model used by EIA. The EPSA Side Case input assumptions were based mainly on the final release of the 2015 Annual Energy Outlook (AEO 2015), with a few updates that reflect current technology cost and performance estimates, policies, and measures, including the Clean Power Plan and

[a] Staff from DOE's Office of Energy Policy and Systems Analysis authored this description.
[b] The version of the National Energy Modeling System (NEMS) used for the EPSA Side Case has been run by OnLocation, Inc., with input assumptions by EPSA. It uses a version of NEMS that differs from the one used by the U.S. Energy Information Administration (EIA).

tax credits. The EPSA Side Case achieves the broad emissions reductions required by the Clean Power Plan. While states will ultimately decide how to comply with the Clean Power Plan, the Side Case assumes that states choose the mass-based state goal approach with new source complement and assumes national emission trading among the states, but does not model the Clean Energy Incentive Program because it is not yet finalized. The EPSA Side Case also includes the tax credit extensions for solar and wind passed in December 2015. In addition, cost and performance estimates for utility-scale solar and wind have been updated to reflect recent market trends and projections, and are consistent with what was ultimately used in AEO 2016. Carbon capture and storage (CCS) cost and performance estimates have also been updated to be consistent with the latest published information from the National Energy Technology Laboratory.

As with the AEO, the EPSA Side Case provides one possible scenario of energy sector demand, generation, and emissions from present day to 2040, and it does not include future policies that might be passed or unforeseen technological progress or breakthroughs. EPSA-NEMS also constructed an "EPSA Base Case" scenario, not referenced in this report, which is based primarily on the input assumptions of the AEO 2015 High Oil and Natural Gas Resource Case. Projected electricity demand values forecast by the EPSA Base Case and Side Case are very close to each other (within 3% by 2040). However, the values forecast by the EPSA Base Case are closer to those that were ultimately included in the AEO 2016 Reference Case.

EPSA Side Case data also are used when most-recent (2014) metrics are reported as a single year or are plotted with future projections. Doing so ensures consistency between current and forecasted metrics. Overlapping years between historical data and data modeled for forecasts are not necessarily equal. Historical data are revised periodically as EIA gathers better information over time, while forecasted cases, which report a few historical years, do not change once they are released to the public.

List of Acronyms and Abbreviations

Acronym / Abbreviation	Stands For
ACEEE	American Council for an Energy-Efficient Economy
AEO	Annual Energy Outlook
AMI	advanced metering infrastructure
AMO	DOE Advanced Manufacturing Office
ARRA	2009 American Recovery and Reinvestment Act
ASHRAE	American Society of Heating, Refrigerating, and Air-Conditioning Engineers
BEV	Battery Electric Vehicle
CAFE	Corporate Average Fuel Economy
CAISO	California ISO
CBECS	Commercial Buildings Energy Consumption Survey
CFLs	compact fluorescent lamps
CHP	Combined Heat and Power
CO^2	carbon dioxide
CPP	Clean Power Plan
CPP	Critical Peak Pricing
CPUC	California Public Utilities Commission
CSE	cost of saved energy
CUVs	crossover utility vehicles
DCLM	Direct Control Load Management
DER	Distributed Energy Resources
DOE	U.S. Department of Energy
DSM	demand side management
DSO	Distribution System Operator
EAC	DOE's Electricity Advisory Committee
EERS	energy efficiency resource standard
EIA	U.S. Energy Information Administration
EM&V	Evaluation, Measurement, and Verification
EMCS	Energy Management Control Systems
EPA	U.S. Environmental Protection Agency
EPSA	DOE Office of Energy Policy and Systems Analysis
ERCOT	Electric Reliability Council of Texas
ESCOs	energy service companies
FCTO	DOE's Fuel Cell Technology Office
FCV	Fuel Cell Vehicle
FEMP	Federal Energy Management Program
FERC	Federal Energy Regulatory Commission
FFV	Ethanol Flex-Fuel Vehicle
FITs	feed-in tariffs
FRCC	Florida Reliability Coordinating Council
GDP	gross domestic product

Acronym / Abbreviation	Stands For
GHG	greenhouse gases
GWP	global warming potential
HEVs	hybrid electric vehicles
HOV	high-occupancy vehicle
HVAC	heating, ventilation, and air-conditioning
Hz	hertz
ICEs	internal combustion engines
ICLEI	International Council for Local Environmental Initiatives
ICT	information and communication technologies
IDM	Industrial Demand Module
IECC	International Energy Conservation Code
IEMS	Industrial Energy Management Systems
IL	Interruptible Load
INL	Idaho National Laboratory
IRP	integrated resource planning
ISO	Independent System Operator
ISO-NE	ISO-New England, Inc.
ITC	investment tax credit
kWh	kilowatt-hours
LBNL	Lawrence Berkeley National Laboratory
LCOE	levelized cost of electricity
LCR	Load as a Capacity Resource
LDV	light-duty vehicle
LED	light emitting diode
LEED	Leadership in Energy and Environmental Design
Li-ion	Lithium-ion
LMP	locational marginal pricing
LR	learning rate
LSE	load serving entity
MATS	Mercury and Air Toxics Standards
MECS	Manufacturing Energy Consumption Survey
MELs	Miscellaneous Electric Loads
MISO	Midcontinent Independent System Operator
MMWh	million megawatt-hours
MRO	Midwest Reliability Organization
MRO-MAPP	Midwest Reliability Organization-Mid-Continent Area Power Pool
MUSH	municipalities, universities, schools, and hospitals
NEMS	National Energy Modeling System
NERC	North American Electricity Reliability Council
NPCC	Northeast Power Coordinating Council
NPCC-NE	NPCC-New England

Acronym / Abbreviation	Stands For
NPCC-NY	NPCC-New York
NREL	National Renewable Energy Laboratory
NYISO	New York ISO
ORNL	Oak Ridge National Laboratory
PACE	Property Assessed Clean Energy
PC	personal computer
PCTs	programmable communicating thermostats
PEV	plug-in electric vehicle
PHEV	Plug-in Hybrid Electric Vehicle
PJM	PJM Interconnection, LLC
PTC	production tax credit
PV	photovoltaic
QER	Quadrennial Energy Review
QTR	Quadrennial Technology Review
R&D	research and development
RD&D	Research, development, and deployment
RECS	Residential Energy Consumption Survey
RETI	Real estate business trust
REV	"Reforming the Energy Vision"
RFC	Reliability First Corporation
RTO	Regional Transmission Organization
RTP	real-time pricing
SDG&E	San Diego Gas and Electric
SEIA	Solar Energy Industries Association
SERC	Southeast Electric Reliability Council
SERC-E	Southeast Electric Reliability Council -East
SERC-N	Southeast Electric Reliability Council -North
SERC-SE	Southeast Electric Reliability Council -Southeast
SGIG	Smart Grid Investment Grant
SPP	Southwest Power Pool, Inc.
SSL	solid-state lighting
TBtu	trillion British thermal units
TOU	time-of-use pricing
TRE	Texas Reliability Entity
TRE-ERCOT	TRE-Electric Reliability Council of Texas
TWh	terawatt-hours
USDA	U.S. Department of Agriculture
V2B	vehicle-to-building
V2H	vehicle-to-home
VAR	volt-ampere reactive
VOS	value of shipments
VTO	DOE's Vehicle Technologies Office

Acronym / Abbreviation	Stands For
WECC	Western Electricity Coordinating Council
WECC-CA-MX	WECC-California-Mexico Power
WECC-NWPP	WECC-Northwest Power Pool
WECC-RMRG	WECC-Rocky Mountain Reserve Group
WECC-SRSG	WECC-Southwest Reserve Sharing Group
ZEV	Zero Emission Vehicle
ZNEB	Zero-Net Energy Building

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Appendix: Evaluation, Measurement, and Verification of Energy Efficiency and Distributed Energy Resource Activities

This appendix describes current energy efficiency and distributed energy resource (DER) evaluation practices, issues associated with conducting reliable and cost-effective evaluation, and trends that may indicate how evaluation may be conducted and used over the next 25 years. Broadly, energy efficiency and DER evaluation activities include impact evaluations, savings projections (e.g., potential studies), process evaluations, market evaluations, and cost-effectiveness assessments. While terminology is not universally consistent within the efficiency industry, the term EM&V—evaluation, measurement, and verification—is often used as a catchall for all of these activities. Many associate the term EM&V with activities primarily designed to evaluate the impact of energy efficiency and DER programs or measures, which is a focus of this appendix. Also covered in this appendix are barriers to improving the application and quality of EM&V and the quality and availability of resulting data, policies that can help overcome those barriers, and gaps in our understanding. See the definitions of select EM&V terms that follow. Documenting the benefits of energy efficiency and DERs using credible and transparent methods is a key component of successfully implementing and expanding the role and efficacy of these resources. Therefore, providing evaluation-based data is not an end unto itself but an effective tool for supporting the adoption, continuation, and expansion of energy efficiency and DERs that are discussed in the body of this report.

Figure 7.38. EM&V cycle[1]

Documenting impacts of energy efficiency and DERs can improve performance of policies, programs, and regulations supporting these activities.

Definition of Select EM&V Terms[2]

Baseline is a set of conditions that would have occurred without implementation of the energy efficiency activity. Baseline conditions are sometimes referred to as *business-as-usual.*

Deemed savings value, also called *stipulated savings value,* is an estimate of energy or demand savings for a single unit of an installed energy efficiency measure that: (1) has been developed from data sources and analytical methods that are widely considered acceptable for the measure and purpose and

(2) is applicable to the situation being evaluated. Individual parameters or calculation methods can also be deemed.

Demand savings is the reduction in electric demand from the baseline to the demand associated with the higher-efficiency equipment or installation. This term, in units of kilowatts (kW), is usually applied to billing demand to calculate cost savings or peak demand for equipment sizing purposes.

Energy savings is the reduction in electricity consumption from the baseline to the demand associated with the higher-efficiency equipment or installation. This term, in units of kilowatt-hours (kWh), can be applied to hourly, monthly, seasonal, annual, or lifetime savings.

Evaluation is the conduct of any of a wide range of assessment studies and other activities aimed at determining the effects of a program (or a portfolio of programs).

EM&V is a catchall term used to describe the processes associated with determining both program and project impacts (versus a wider range of evaluation activities).

Gross savings is the change in energy consumption, demand, or both that results directly from program-related actions taken by participants in an energy efficiency policy or program, regardless of why they participated.

Impact evaluation is an evaluation of the program-specific, directly or indirectly induced, changes associated with an energy efficiency program (e.g., changes in energy use).

Market evaluation is an evaluation of the change in the structure or functioning of a market or the behavior of participants in a market, which results from one or more program efforts. Typically, the resultant market or behavior change leads to an increase in the adoption of energy efficient products, services, or practices.

Measurement and verification (M&V*)* can be a stand-alone activity or a subset of program impact evaluation. In either case, it is associated with the documentation of energy savings at individual sites or projects.

Net savings is the change in energy consumption, demand, or both that is attributable to a particular energy efficiency policy or program.

Persistence is the duration of an energy-consuming measure, taking into account business turnover, early retirement of installed equipment, technical degradation factors, and other reasons that measures might be removed or discontinued.

Process evaluation is a systematic assessment of an energy efficiency program for the purposes of documenting program operations at the time of the examination, and identifying and recommending improvements to increase the program’s efficiency or effectiveness for acquiring energy resources while maintaining high levels of participant satisfaction.

Randomized controlled trial (RCT) is a type of experimental program evaluation design in which energy consumers in a given population are randomly assigned into two groups: a treatment group and a control group. The outcomes for these two groups are compared, resulting in program energy savings estimates.

Spillover (participant and non-participant) refers to reductions in energy consumption, demand, or both caused by the presence of an energy efficiency program, beyond the program-related gross savings of the participants and without direct financial or technical assistance from the program. There can be participant and non-participant spillover. *Participant spillover* is the additional energy savings that occur as a result of the program's influence when a program participant independently installs incremental energy efficiency measures or applies energy-saving practices after having participated in the energy efficiency program. *Non-participant spillover* refers to energy savings that occur when a program non-participant installs energy efficiency measures or applies energy savings practices as a result of a program's influence.

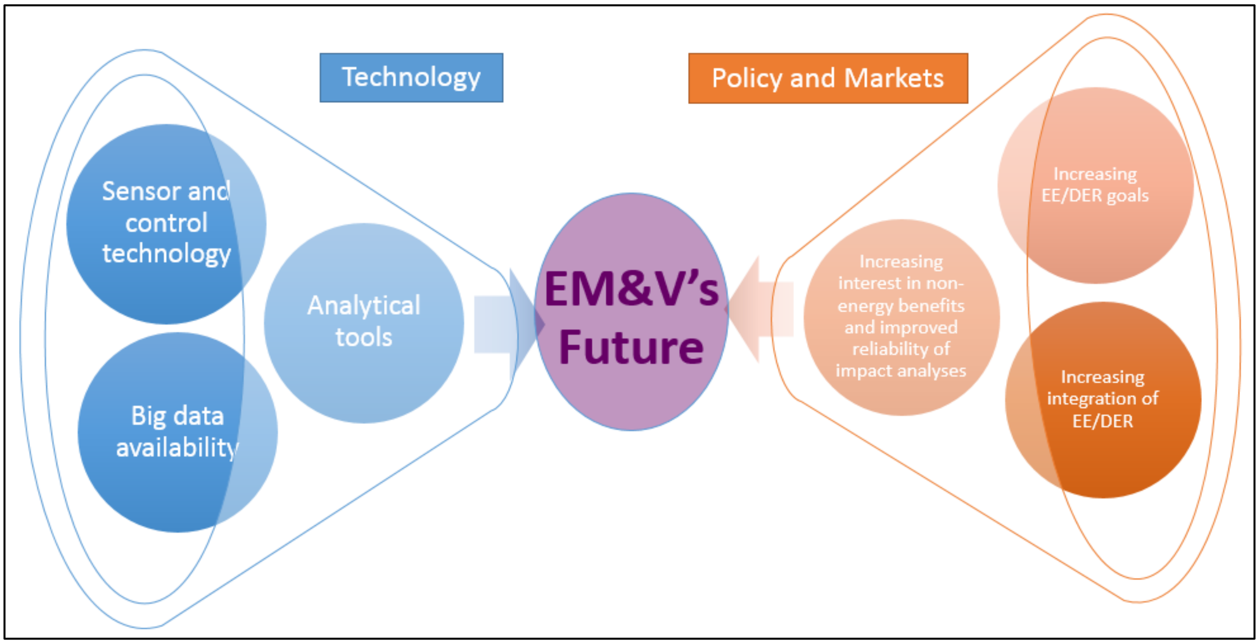
Technical reference manual (TRM) is a resource document that includes information used in program planning and reporting of energy efficiency programs. It can include savings values for measures, engineering algorithms to calculate savings, impact factors to be applied to calculated savings (e.g., net-to-gross ratio values), source documentation, specified assumptions, and other relevant material to support the calculation of measure and program savings—and the application of such values and algorithms in appropriate applications.

Verification is an assessment by an independent entity to ensure that the energy efficiency measures have been installed correctly and could generate the predicted savings. Verification may include assessing baseline conditions and confirming that the measures are operating according to their design intent. Site inspections, phone and mail surveys, and desk review of program documentation are typical verification activities.

7.7.1 Key Findings and Insights

A number of technology, policy, and market drivers will influence the future of EM&V for energy efficiency and DERs (Figure 7.39). The following findings are organized by these three types of drivers. These findings may help predict future trends regarding uses of EM&V and the value placed on various metrics assessed with EM&V, and thus the methods, tools, and services that will need to be developed. Together with the EM&V research gaps identified in Section 7.7.5, these findings lead to the insights described here. An overarching insight is that if stakeholders develop greater confidence in the benefits of energy efficiency and DER investments without the need to document such benefits, the importance placed on ex-post EM&V may be reduced. That may lead to greater use of ex-ante deemed savings values and simpler verification activities. On the other hand, higher goals for energy efficiency and DERs, the need to assess new energy efficiency and DER technologies and strategies, increased use of energy efficiency and DER technologies in the operation of distribution and transmission systems, increased use of performance contracting and third-party financing, and expanded goals for reducing greenhouse gas emissions may drive greater interest in all types of EM&V data (including energy and non-energy impact metrics). This will be particularly true if new tools can make EM&V more accessible by reducing EM&V transaction costs, increasing data reliability, and increasing timeliness of data availability.

Figure 7.39. Drivers for future energy efficiency and DER EM&V



7.7.1.1 *Technology Drivers*

Findings:

- Advances in the EM&V industry are continually occurring with more experience and accelerated development of new technologies and analytical tools. Prominent development areas include continuous energy management, top-down evaluation, M&V 2.0, and assessments of non-energy impacts.
- M&V 2.0 is an area of particular interest, where potential advances are based on access to better and more end-use energy consumption data from smart meters, advanced metering infrastructure (AMI), smart devices, and wireless and non-intrusive load metering (big data), as well as improved analytical tools. Such tools include automated M&V, benchmarking, and behavior analytics.
- While there is increased interest in M&V 2.0 advances, other approaches to evaluation (deemed savings and control group approaches), particularly for energy efficiency, are likely to continue to be highly relevant to energy and demand savings determinations.

Insights: Greater access to real-time and higher-time resolution data on energy consumption and independent variables (e.g., occupancy, plug load characteristics, control system settings), combined with the further development and implementation of advanced EM&V methods (e.g., M&V 2.0), may be able to provide deeper insights into energy use and energy use reduction and improve the speed at which change in energy consumption is determined at the desired levels of confidence (Section 7.7.5.2).

Further use of and refinements to (E)M&V 2.0 and auto-M&V data collection and analysis, driven in part by private sector providers of such services under the Software as a Service (SaaS) business models, could result in lower cost and more reliable and timely EM&V-based information. By flagging performance issues associated with energy efficiency and DER projects and programs (such as lower than expected savings due to equipment failures or changing occupant behaviors), these EM&V advances can support near real-time corrections that improve performance. However, to date there has been limited application of (E)M&V 2.0 processes (Sections 7.7.3.2 and 7.7.5.7).

Transmission and distribution system efficiency, building energy codes, appliance and equipment standards, and energy efficiency and DER financing programs are areas where EM&V is evolving (Sections 7.7.5.8, 7.7.5.9, and 7.7.5.10).

7.7.1.2 *Policy Drivers*

Findings:

- Energy efficiency historically has been driven primarily by policy objectives associated with reducing energy consumption and displacing conventional, more-expensive, and more-polluting generation resources. Over time these policy objectives, as well as objectives for DER-related policies, have expanded to include other public policy goals, such as local economic development, grid resiliency, and renewable energy integration.
- These new policy drivers can affect both the metrics assessed through the EM&V process and the relative importance of accurately determining the impacts of energy efficiency and DERs. Accuracy can take on increased importance as public and private funders invest more in energy efficiency and DERs, and policy makers rely more on these resources for meeting electricity needs reliably and cleanly.
- One outcome of these higher expectations for energy efficiency and DERs is that the types of programs may expand—e.g., to include more aggressive energy codes and standards, more programs to reduce energy losses in transmission and distribution, more energy efficiency financing programs, and more integrated demand-side management (DSM) programs. This expansion of energy efficiency and DER program types will likely lead to the need for reliable EM&V for an expanding list of program types.
- For energy efficiency and DER activities supported with utility customer funds or public funds, there is a continuing interest in understanding the level of impacts—particularly electricity savings—that can be attributed to the supported intervention (often referred to as net savings) versus the total impacts (often referred to as gross savings). However, this level of interest varies depending on the perspective of involved parties. For example, a utility regulator that is connecting performance of energy efficiency programs to a utility's authorized earnings may want to know the attributable savings associated with the utility's energy efficiency programs. On the other hand, a governor or air regulator may only be interested in gross savings metrics for energy efficiency programs for the purposes of resource planning or emissions accounting.
- Supporters of M&V 2.0 may encourage jurisdictions to adopt gross savings and existing condition baselines as standards for measurement, as in California's 2015 Assembly Bill 802.[3] Such baseline standards can complicate issues of whether programs are delivering energy savings beyond what would have occurred absent the energy efficiency or DER program intervention—which can be an important objective of publicly or utility customer-funded programs. Thus, another possible outcome is that EM&V 2.0 tools eventually develop the capacity to overcome this limitation of only using existing condition baselines.

Insights: Increasing interest in non-energy impacts will drive increasing effort for documenting these impacts, particularly for (Sections 7.7.3.3 and Section 7.7.5.11):

- avoided emissions
- grid impacts
- economic development—e.g., jobs
- consumer benefits—e.g., increased comfort and productivity

Further development of approaches for defining baselines and assessing net savings associated with determining savings attribution will enable greater understanding of programmatic approaches to increasing the levels of energy efficiency and DER penetration and impacts (Sections 7.8.3.2 and 7.8.6.5).

Reliability of estimated measure lives and savings persistence for energy efficiency is increasingly important, indicating an increasing need for more research and documentation on these factors and better documentation of verification activities (See sections 7.7.4, 7.7.5.1, and 7.7.5.5,).
Top-down evaluation is gaining more traction as a bottom-line indicator of performance for energy efficiency and DER programs and policies. More pilot programs to test this approach, with government support, will need to be conducted, with a focus on improving access to the data required for such evaluations (Sections 7.7.3.1 and 7.7.5.7).

7.7.1.3 *Market Drivers*

Findings:

- The objectives and perspectives of stakeholders involved in energy efficiency and DER activities also drive energy efficiency and DER markets. These diverse stakeholders include policy-makers, energy and environmental regulators, utilities, contractors, electricity consumers, businesses, and environmental advocates. Perspectives vary even within each of these groups. For example, perspectives of investor-owned utilities can be different from perspectives of municipal utilities and rural electric co-ops, and residential consumers may have different perspectives than industrial consumers. Following are three examples as they relate to EM&V:

    - Many consumers do not necessarily implement energy efficiency measures for the energy savings but to obtain other benefits such as increased system performance (e.g., variable speed drives in factories) or comfort (insulation in homes). For these consumers, the importance of a reliable energy savings determination (via M&V) may be quite limited. On the other hand, utility regulators and utilities themselves are often quite concerned with knowing, reliably, how energy efficiency and DER investments are performing.

    - It is typical to define baselines for utility customer programs, or a requirement in building energy codes or appliance or equipment standards, as some form of common practice. This is because it often makes sense from a public policy perspective not to use program funds to incent consumers to buy what they would have normally purchased or what they would be required to purchase—the attribution issue discussed above. The result is that it is common to define baselines for utility customer-funded programs based on existing building energy codes, appliance or equipment standards, or other considerations such as the remaining functional life of the equipment or systems being replaced.

- However, consumers look for savings from a baseline of what they had before they implemented a project. In effect, they want to see the savings as compared to past energy bills, not hypothetical bills. Also, for many energy service company (ESCO) contracts for large commercial customers, baselines are defined based on the existing condition of a specific building. Thus, baselines from which savings are determined can differ across the types of delivery mechanisms, particularly for energy efficiency activities.

- From an overall electric grid perspective, DERs such as demand response and energy storage can provide benefits for reliability and integration of renewable resources. For utilities and grid operators, these benefits can exceed in importance individual consumer energy savings and drive interest in new metrics and new EM&V tools and approaches. Similarly, increased interest in reducing greenhouse gas emissions also can lead to new metrics, focusing on avoided emissions from the grid.
- Therefore, EM&V uses, metrics, and even the need for EM&V, as well as requirements for reliability and timeliness of the EM&V results, vary by stakeholder. Much of the EM&V conducted in the United States to date for energy efficiency and demand response resources has been defined by the administrators and regulators of utility customer-funded programs. This could change in the future with evolving energy efficiency and DER activities and whether more or less of the funds for these activities are coming from the public (taxpayers), utility customers, or private financing providers. Meeting the needs of various stakeholders in turn drives energy efficiency and DER markets to focus on different strategies and different metrics for assessing these metrics, which in turn affects the EM&V to be conducted.

Insights: Standardization across the energy efficiency and DER industries of EM&V terminology, approaches, and reporting, as well as training and certification of EM&V professionals, is improving, in part driven by federal and state efforts and increased use of efficiency and DER resources for environmental protection and as bulk electric system reliability resources. Areas of particular focus for standardization could include the following (Section 7.7.5.3):

- Defining consistent baseline option definitions and when each can or should be applied, with clarifications on the difference between net savings, common practice baselines, and savings attribution
- Greater understanding of the advantages and disadvantages of the various approaches for assessing impact attribution and, thus, how savings attribution metrics can be appropriately applied
- Reporting of energy efficiency and DER metrics with consistent definitions and in consistent formats for benchmarking and comparison
    - Deemed savings are becoming more prevalent for energy efficiency equipment retrofit measures, with a corresponding increase in the validity of how the values are applied, documented, and used in order to decrease EM&V costs and increase certainty for energy efficiency funders, contractors, and consumers. The use of deemed savings requires that there be an understanding that the savings from implemented measures can vary based on usage, which requires caution in how deemed savings are applied. The appropriate use of deemed savings may be limited to behavior-based energy efficiency actions unless significant amounts of data can be provided that support such stipulation of average impacts (Sections 7.7.2.1 and 7.7.5.7).
    - Statistical analyses using control group approaches (randomized control trials and quasi-experimental) will continue as a preferred option for documenting impacts of mass-market energy efficiency and demand response strategies, such as whole-house retrofits. However, for control groups to be used more broadly, they will need to be adapted for applications where control groups cannot be readily identified (such as efficiency projects for nonresidential buildings) or where limiting access to programs in order to form control groups is seen as problematic. New efforts may be forthcoming to find ways to apply control group approaches to more program types, as well as to improve the methods themselves (Sections 7.7.2.1 and 7.7.5.7).

7.7.2 EM&V Characterization

This section describes current EM&V trends, approaches, and practices for determining energy savings, avoided air emissions, and other non-energy impacts. While the energy impacts of some DERs, such as distributed generation, can be directly measured, the impacts of energy efficiency and demand response activities, such as energy savings and demand savings, cannot be directly measured. Instead, impacts are estimated based on counterfactual assumptions. The need for counterfactual assumptions can create uncertainty and add time to the EM&V process, as well as create a fundamental need to balance the reliability of impact estimates with the cost of obtaining such estimates through EM&V. EM&V costs are difficult to document and even define, but are generally considered to add 1% to as much as 15% in rare cases to the cost of energy efficiency activities, with EM&V costs for third-party evaluation of utility DSM efficiency programs typically on the order of 3% to 5% of total expenditures for these programs. Thus, while EM&V has substantial benefits for providing data to assess energy efficiency and DER activities, associated uncertainty, delays in program results, and costs can limit the commitment to and confidence in energy efficiency activities.

This appendix covers ex-post evaluation of energy efficiency and DER activities. Another form of evaluation is ex-ante determination of savings potential. These determinations are documented in feasibility studies or potential studies, which are intended to assess potential savings and benefits from future projects or programs, respectively.

An industry standard guide to EM&V is the SEE Action Energy Efficiency Program Impact Evaluation Guide. It describes and provides guidance on approaches for determining and documenting energy and non-energy benefits resulting from energy efficiency programs and portfolios of programs. It specifically focuses on impact evaluations for ratepayer funded programs designed to reduce facility (e.g., home, commercial building, factory) energy consumption, demand, or both—as well as related air emissions. The guide is available at: www.seeaction.energy.gov.

7.7.2.1 *Generic EM&V Categories and Methods*

Evaluation includes any of a range of retrospective assessment studies and other activities aimed at determining the effects of energy efficiency and DER policies, portfolios, programs, or projects. Evaluation can document metrics such as performance (e.g., energy and demand savings, avoided air emissions), changes in markets (e.g., changes in product and services availability and pricing), and cost-effectiveness. There are three broad categories of energy efficiency and DER evaluations: impact evaluations, process evaluations, and market evaluations.

This appendix focuses on impact evaluation of both (1) programs, portfolios, and policies, and (2) individual projects. Evaluation is the typical term associated with assessing programs (and program portfolios and policies); M&V is associated with assessing project impacts. There can be some overlap between M&V and evaluation since programs are often made up of individual projects. Thus, impacts determined with M&V for all, or representative, projects in a program can be combined to assess the impacts of the underlying program.

- Evaluation of energy efficiency and demand response program and portfolio evaluation started in the 1980s, with the development of programs operated by utilities. Starting in the early 1990s, handbooks, guidelines, and protocols were developed for utility DSM programs, some prepared by individual utilities or state public utility commissions and others supported by the U.S. Department of Energy (DOE). While evaluations also can be performed for other DER strategies, such as distribution generation and energy storage, the focus of EM&V activities for the last 40 years has been on energy efficiency and demand response.

- M&V focuses on assessing individual measures or project impacts using project site measurements and inspections (verification) activities. M&V was first developed for energy efficiency in the 1980s to support the nascent ESCO industry to document savings, which continues to be critical for ESCO performance-based contracts with savings guarantees. The National Association of Energy Service Companies developed the first M&V guidance documents. Shortly thereafter, in the 1990s, the North American Energy M&V Guidelines (NAEMVP), the Federal Energy Management Program (FEMP) M&V Guidelines, and the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) M&V Guidelines were developed with support from DOE and industry groups. Other efforts at individual companies, utilities, and universities also supported the creation of M&V methodologies, metering, and analysis tools. The FEMP and ASHRAE guidelines have been expanded and modified over the last two decades. The NAEMVP evolved into the International Performance Measurement and Verification Protocol (IPMVP), now the most recognized international M&V guidance document

Examples of Industry-Standard M&V Protocols and Guidelines

IPM VP: International Performance Measurement and Verification Protocol: Core Concepts 2015, Efficiency Valuation Organization. www.evo-world.com.

FEMP: M&V Guidelines: Measurement and Verification for Performance-Based Contracts, Version 4.0. Prepared for the U.S. Department of Energy Federal Energy Management Program. http://energy.gov/eere/femp/downloads/mv-guidelines-measurement-and-verification-performance-based-contracts-version.

ASHRAE Guideline 14: Measurement of Energy and Demand Savings. American Society of Heating, Refrigerating, and Air Conditioning Engineers. http://www.ashrae.org.

U.S. DOE UMP: Uniform Methods Project. http://energy.gov/eere/about-us/ump-protocols.

The IPMVP defines four M&V options for determining the energy and demand savings from projects: two end-use metering (retrofit isolation) approaches (IPMVP Options A and B), energy use data (billing data) regression analysis (IPMVP Option C), and calibrated computer simulation (IPMVP Option D). In addition, DOE has an M&V initiative called the Uniform Methods Project (UMP). Starting in 2013, DOE began publishing UMP protocols to determine measure and project energy savings. The protocols provide standardized, common practice M&V methods for determining gross energy savings for many of the most common residential and commercial measures and programs offered by administrators of energy efficiency programs in the United States for utility customers.

Today, most utility efficiency and DER programs have some form of evaluation guidelines in place. M&V is one way that programs are evaluated; for example, M&V is applied to a sample of projects, and the results are applied to the entire program population of projects. However, there are two other distinct methods commonly used for program assessments: (1) using deemed (also called *stipulated*) savings values and calculations, and (2) comparison group methods. Using deemed savings is not considered M&V, as M&V (as defined by the IPMVP) always requires some level of site measurements (see text box).

Industry Standard Evaluation Approaches/Methods for Energy Efficiency and Demand Response

Deemed savings values are estimates of electricity savings for a single unit of an installed energy efficiency measure that: (1) have been developed from data sources (such as prior metering studies) and analytical methods that are widely considered acceptable for the measure and purpose, and (2) are applicable to the situation under which the measure is being implemented. When deemed savings are used to quantify electricity savings, a separate verification process is needed to confirm the quantity of units installed. Deemed savings should be updated, as needed, based on measurement-based evaluation information.

Measurement and verification is the process of determining savings from individual energy efficiency measures or projects. The IPMVP defines **two retrofit isolation options** and **two whole-facility options:**

- *Retrofit isolation:* Assessing savings from each energy efficiency measure individually (IPMVP Options A & B). Verification is an integral part of Options A and B since the measurement process involves direct observation of all or a sample of the affected equipment.
- *Whole facility:* Collectively assessing savings from all energy efficiency measures in a facility (IPMVP Option C, review of energy bills, or Option D, calibrated simulation). With Option C, the energy consumption data speak for themselves with respect to savings, and thus inspections may not be required. However, it is a best practice to include some site inspections. With Option D the calibration process typically involves some level of site inspections and thus verification.

Comparison group EM&V methods determine program savings based on the differences in energy consumption between a comparison group and program participants. Comparison group approaches include randomized control trials and quasi-experimental methods. Because the effects of implemented measures are reflected in the observed participant-comparison differences, separate verification is not required.

For energy efficiency, determining energy savings includes: (1) verifying that a measure or project has been installed and, in some cases, that it is properly operating, and (2) quantifying savings. With deemed savings, verification is a critical element of the overall evaluation process. As discussed in the text box, verification may or may not be an integral part of M&V activities. However, under the comparison group method, the evaluation approach may in effect include both steps in a single process.

The United States' EM&V experience has been used in other countries through programs such as those of the World Bank, United States Agency for International Development, and the International Energy Agency (IEA). An example of IEA-organized transfer of EM&V technology and experience is efforts of the IEA Demand Side Management Energy Efficiency program, an international collaboration of 16 countries and sponsors, including the United States, working together to develop and promote opportunities for DSM.[4] In addition, the Energy Efficiency Division at the IEA has relied on U.S. experts for many of its publications that address EM&V topics.[a]

[a] See the IEA's Energy Efficiency webpage for a list of publications, many featuring United States' programs and case studies, accessed February 25, 2016: http://www.iea.org/topics/energyefficiency/.

7.7.2.2 *EM&V Practices—Energy and Demand Savings*

Current Industry EM&V Practices

Impact evaluation has primarily been used for, and is most developed for, utility energy efficiency and demand response programs and projects implemented directly by ESCOs. Energy efficiency EM&V strategies in wide use today—including budget levels, oversight procedures, and preferred methods—are derived from utility regulatory agency requirements together with industry standard energy efficiency EM&V and M&V protocols (see text box). For a given program or project, the specific EM&V approach that is applied depends on the type of activity, overall policy objectives, available budgets, and other factors.

Demand response program EM&V has also been developed based primarily on utility program impact evaluations, starting with demand response programs in the 1990s in states such as California, Colorado, Minnesota, and Texas. As with energy efficiency, demand response EM&V involves comparing measured (actual) energy consumption over a specific period of time (e.g., utility coincident peak demand hours) with a counterfactual demand either in aggregate (for example, with a residential air-conditioning cycling program) or per site (such as with an industrial demand response program). Today, the most well-known documented M&V methods are those used by two Independent System Operators (ISOs)—ISO New England (ISO-NE) and PJM, first implemented in 2007 and 2009, respectively. These organizations have established forward capacity markets that pay suppliers of demand-side resources. The oversight and quality control of energy efficiency resources that are bid into the market are governed by M&V rules and requirements defined in evaluation manuals established by these organizations.[5]

For building energy codes and product energy efficiency standards, the situation is different with respect to retrospective EM&V. While ex-ante estimates of the impacts of building energy codes and product standards are completed regularly as they are developed and adopted, ex-post quantification of energy savings from building energy code adoption and compliance activities is not as common or well established. The primary code adoption and compliance impact evaluation work to date has been completed in six states (Arizona, California, Massachusetts, New York, Oregon, Rhode Island, and Washington) and at Pacific Northwest National Laboratory (PNNL)[6] for DOE. These states have regulatory structures that define acceptable procedures for quantifying savings from building energy code programs and attribute code program savings to energy efficiency program administrators.[7] Similarly, only a limited number of ex-post energy saving studies have been completed for product energy standards. California has conducted three cycles of energy code and appliance standard evaluations for its statewide Codes and Standards Program.[8]

DOE released a federal Funding Opportunity Announcement, "Strategies to Increase Residential Energy Code Compliance Rates and Measure Results,"[9] in 2014. To support the evaluation of pilot programs conducted under this initiative, PNNL is modifying evaluation procedures, released in 2010,[10] to develop a new residential energy code compliance and energy savings methodology.

EM&V performed for distributed generation and storage at utility customer sites is far more straightforward because, under current practice, it does not involve development of a counterfactual scenario. For example, the output of solar photovoltaic (PV) systems is simply measured with a utility-grade meter to determine generation output. Metrics reported for storage, such as round-trip energy losses, also use a utility-grade meter to measure electricity input and output.

Table 7.10 provides a heuristic indication of which EM&V approaches are used for various types of programs and projects. The most common EM&V approach is deemed savings values. These values, if properly developed and applied, can support reliable savings estimates. They also provide certainty for all the parties involved in an energy efficiency or DER transaction.

Table 7.10. Common EM&V Approaches for Select Energy Efficiency and Demand Response Categories and Project Types

	EM&V Methods		
	Deemed Savings	Measurement and Verification	Comparison Groups
Program Categories			
Utility Programs: direct action measures[a]	Very common	Common	Common
Utility Programs: indirect action measures[b]	Common	Not common	Common
ESCO Energy Efficiency Projects	Common	Very common	Not used
Building Energy Codes	Common	Can be used	Can be used
Product Standards	Common	Can be used	Can be used
Energy Storage	Common	Very common	Can be used
Industrial Strategic Energy Management and Voluntary Efforts	Common	Common	Not used

[a] *Direct action programs* are those that result in the *direct, explicit* installation of pieces of equipment or systems, as well as modifications of equipment, systems, or operations. Examples include consumer product rebates, incentives or technical assistance for construction of new buildings, and street lighting retrofits.
[b] *Indirect action programs* are those intended to *facilitate or indirectly result in installation* of equipment or systems, as well as modifications of equipment, systems, or operations. Examples include consumer behavior programs; marketing, education and outreach programs; and workforce education and training programs.

Demand Response	Can be used	Very common	Can be used
Distributed Generation: PV	Common	Very common	Can be used
Distributed Generation: CHP	Can be used	Very common	Can be used
Storage	Can be used	Very common	Can be used
Project Types			
Simple, Well-Defined Individual Projects	Very common	Can be used	Not used
Complex, Unique Individual Projects	Not used	Very common	Not used
Large Number of Relatively Homogenous Projects	Very common	Can be used	Common

Technical Reference Manuals (TRMs) are databases of standardized, state- or region-specific deemed savings calculations and associated deemed savings values for well-documented efficiency measures. Efficiency program administrators and implementation contractors use TRMs to reduce evaluation costs and uncertainty. There are approximately 20 TRMs in use across the United States. A 2011 report found that TRMs are very valuable, but there is wide variation in methodologies for estimating savings and actual values.[11] Some TRMs include information based on prior year evaluations including, in some cases, rigorous metering and analysis. Thus, these TRMs contain robust (reliable) savings values. Many others have values based on what may be considered less rigorous analyses. With the exception of the Northwest Regional Technical Forum, which uses a public peer-review process to determine consistency with clear guidelines, TRMs typically are created by skilled teams of expert consultants, but these teams' methods and assumptions are not necessarily peer-reviewed prior to approval.

The U.S. Environmental Protection Agency (EPA) Clean Power Plan (CPP) indicates that well-crafted and documented deemed savings values are an acceptable EM&V method that can provide consistency, quality Emission Rate Credit values, and cost-effective EM&V. As indicated in the draft CPP EM&V Guidance document, "Ongoing and new state, regional, and federal efforts to improve the quality and documentation of TRMs are encouraged and can support higher-quality savings values for compliance with the EPA's emissions guidelines and reduced EM&V costs."[12] [a] Furthermore, anecdotal information indicates that deemed savings values are very commonly used for savings determinations with utility energy efficiency programs and are also applied in some ESCO projects.

Measurement and verification methods are another approach to EM&V for utility customer-funded energy efficiency and demand response programs as well as ESCO projects. The IPMVP retrofit isolation methods, IPMVP Options A and B, and the billing analysis approach of using a project's pre-project and post-project utility bills for analysis, appear to be the more common M&V methods, versus calibrated simulations, IPMVP Option D. One study of DOE's Energy Savings Performance Contract program further indicated that for those ESCO projects, the most common M&V approaches were IPMVP Options A and B.[13] These have historical limitations associated primarily with cost of metering (equipment and labor), which project participants are not interested in paying for, particularly over the life of projects. This may be changing with the M&V 2.0 developments discussed in the next section of this appendix.

A third approach, comparison group analyses with non-participant control groups, has been used for decades for residential efficiency programs with large numbers of relatively homogenous participants. There has been renewed interest in this approach for a wide range of program types, as a potential gold standard of savings determination. At least in theory, comparison group analyses assess the savings just associated with the efficiency activity or DER activity, and not changes in energy consumption or demand associated with outside factors such as changes in the economy and energy prices or savings from those consumers who would have completed the projects outside of program influences (e.g., free riders).[b] The challenges for comparison group approaches include reasonably applying them to populations of non-homogenous, customized projects (such as efficiency in commercial, institutional, and industrial facilities) and structuring a control group; particularly if done randomly (at least in part to

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[a] This is also consistent with EPA's final CPP Emission Guidelines, which indicate that state plans must require "a demonstration of how savings will be quantified and verified by applying industry best-practice protocols and guidelines, as well as explanation of the key assumption and data sources used." From FR 64909, accessed May 5, 2016, https://www.gpo.gov/fdsys/pkg/FR-2015-10-23/pdf/2015-22842.pdf.

[b] How well the control group approach, in practice, achieves true incremental and net impacts depends on the specific approach applied (randomized control trials are more reliable than quasi-experimental methods) and how well the approach is implemented.

avoid self-selection biases), that may mean that some eligible consumers do not get to participate in the efficiency activity. Costs for well-designed and implemented control group analyses, especially when randomized control groups are used, may exceed costs for other approaches, particularly the use of deemed savings.

7.7.2.3 *EM&V Practices—Energy Impact Metrics*

Energy and Demand Savings

EM&V is used to determine both energy and demand savings. The most typical metrics for energy savings are annual and lifetime savings. In some cases, monthly or even hourly savings are determined for purposes such as detailed cost-effectiveness analyses or for troubleshooting possible deficiencies in the performance of efficiency measures. Metrics for demand savings can be more complex. They are presented in the form of annual or seasonal average savings, maximum demand reductions, or demand reductions coincident with peak demand characteristics of the electric grid. Methods used to estimate demand savings may not be the most appropriate method to estimate energy savings—and vice versa.[14] Some approaches for estimating annual energy savings (such as monthly billing data analysis) do not provide peak demand savings directly. Table 7.11 is a summary of approaches to determine peak demand and time-differentiated energy savings.

Table 7.11. Demand Savings Determination Approaches for Peak and Time-Differentiated Savings[15]

Approach	Relative Cost	Relative Potential Accuracy	Comments
Engineering Algorithms	Low	Low-Moderate	Accuracy depends on the quality of the input assumptions as well as the algorithm
Hourly Simulation Modeling	Moderate	Moderate	Input assumptions are again important—garbage in, garbage out. Appropriate for HVAC and shell measures and HVAC interaction
Billing Data Analysis	Moderate	Moderate	Typically not useful for peak demand or on/off peak energy analysis
Interval Meter Data Analysis	Moderate	High	Interval meter data not available for many customers. Becoming more feasible with proliferation of advanced metering infrastructure (AMI)
End-Use Metered Data Analysis	High	High	Requires careful sampling and consideration of period to be metered

Gross and Net Savings

There are two common ways in which energy savings are reported for energy efficiency programs funded by utility customers:[16]

- Gross savings: Changes in energy consumption that result directly from program-related actions taken by participants of an energy efficiency program, regardless of why they participated.
- Net savings: Changes in energy use that are attributable to a particular energy efficiency program. These changes may implicitly or explicitly include the effects of free ridership, spillover, and induced market effects.

Free ridership is the program savings attributable to program participants who would have implemented a program measure or practice in the absence of the program. Free ridership savings are included in gross savings, but are typically removed from net savings. *Spillover* refers to additional reductions in energy consumption or demand that are due to program influences beyond those directly associated with program participation. Spillover savings are not included in most gross savings determination methods, but are sometimes included in net savings determinations. *Market effects* refer to "a change in the structure of a market or the behavior of participants in a market that is reflective of an increase in the adoption of energy efficiency products, services, or practices and is causally related to market intervention(s)."[17]

Net savings apply only to certain energy efficiency program categories, primarily programs funded by utility customers and, in the cases where they are evaluated, building energy codes and product standards. ESCO projects and other types of individual consumer actions are only assessed on the basis of gross savings, as the issue of attribution is not relevant to the project participants and funders. In terms of how different jurisdictions define net savings, and which of the above factors are included, a 2012 American Council for an Energy-Efficient Economy study found that states are not consistent as to whether they report gross savings, net savings, or both, and in terms of net savings there appears to be more states making free rider adjustments than spillover adjustments.[18] [a]

Evaluators generally agree that net savings research can be useful for:[19]

- Gaining a better understanding of how the market responds to programs and using that information to modify the program design
- Gleaning insight into market transformation over time by tracking net savings across program years and determining the extent to which free ridership and spillover rates have changed
- Informing resource procurement plans, which require an understanding of the relationship between efficiency levels embedded in base-case load forecasts and additional net reductions from program
- Assessing the degree to which programs effect a reduction in energy use and demand.

Cost-Effectiveness

Cost-effectiveness is of keen interest to policy makers, utility regulators, program providers, and consumers. Definitions of *cost-effectiveness* vary according to the perspectives of different stakeholders. Table 7.12 provides the classic definitions of cost-effectiveness as defined in the California Standard Practice Manual. More recent work to update cost-effectiveness testing frameworks for efficiency and demand response has been recently completed[20] or is underway.[21]

[a] It is important to recognize that the study survey did not specify any particular definition of what qualifies as net or gross savings. Rather, the survey allowed states to categorize their own approach. The report states, "… 21 states (50%) said they reported net savings, 12 states (29%) said gross savings, and 9 states (21%) said they report both (or use one or the other for different purposes). We explored the net savings issue in a little more detail, and asked whether states made specific adjustments for free riders and spillover. Interestingly, while 28 states (67%) indicated they make an adjustment for free riders, only 17 states (44%) make an adjustment for free drivers/spillover."

Table 7.12. Standard Definitions of Cost-Effectiveness for Energy Efficiency[22]

TEST	ACRONYM	KEY QUESTION ANSWERED	SUMMARY OF APPROACH
Participant cost test	PCT	Will the participants benefit over the measure life?	Comparison of costs and benefits of the customer installing the measure
Program administrator cost test	PACT	Will utility bills increase?	Comparison of program administrator costs to supply-side resource costs
Ratepayer impact measure	RIM	Will utility rates increase?	Comparison of administrator costs and utility bill reductions to supply-side resource costs
Total resource cost test	TRC	Will the total costs of energy in the utility service territory decrease?	Comparison of program administrator and customer costs to utility resource savings
Societal cost test	SCT	Is the utility, state, or nation better off as a whole?	Comparison of society's costs of energy efficiency to resource savings and non-cash costs and benefits

The results of impact evaluations typically provide data for cost-effectiveness determinations. Data required can include monetized benefits (primarily energy and demand savings), project costs, program costs, project lifetime and, in some cases, non-energy benefits (see the next section). The findings help judge whether to retain, revise, or eliminate program elements and provide feedback on whether efficiency is an effective investment, compared with energy supply options. The quality of data used for cost-effectiveness determination, particularly factors such as project lifetimes and project costs, varies.[23] As EM&V methods become more accurate and less expensive to administer, they will also help improve the analysis of the cost-effectiveness of energy efficiency program administration.

7.7.3 EM&V Trends

The prior section described current EM&V practices. General trends associated with advancing current practices are improving the quality (i.e., accuracy, reliability) of energy and demand savings estimation as well as non-energy impacts, the speed at which EM&V results are available, and consistency in the terminology and procedures associated with EM&V. These are driven by changes in technologies, policies, and markets (including stakeholder perspectives) as summarized in the Findings and Insights subsection at the beginning of this appendix. In addition to these "natural" or "maturing" improvements in EM&V, this section discusses three specific EM&V approaches and metric trends: top-down evaluation, EM&V 2.0, and impact evaluation of non-energy benefits. The accompanying text box describes continuous energy management, which uses M&V-type information to directly improve the performance of energy efficiency and DER technologies and systems.

Continuous Energy Management

DOE has fostered the development of standardized practices to incorporate energy management into business management through programs such as Better Plants, ISO 50001 and Superior Energy Performance. These programs incorporate transparent and rigorous tracking of energy usage to regularly identify opportunities for continuous improvement in energy performance (energy savings).

See "Current Practice: Energy Efficiency Savings Determination," SEAB Task Force on Federal Energy Management, Sept. 11, 2015, William C. Miller, Lawrence Berkeley National Laboratory

7.7.3.1 *Top-Down Evaluation*

Top-down evaluation involves macroeconomic modeling, in contrast to the EM&V approaches and methods described above which are sometimes referred to as *bottom-up* evaluation. Top-down evaluation involves evaluating portfolios of energy efficiency programs using: (1) aggregate (e.g., utility service area, county, Census block) energy use or per-unit energy consumption indices (e.g., energy consumption per unit of output or per capita), and (2) energy-use driver data (e.g., income, prices, population) to determine savings from portfolios of programs.

Top-down evaluation focuses on the bottom line—reductions in energy use (and/or demand) for a state, region, or utility service territory. This gives top-down evaluation a direct link to (1) demand forecasting and resource planning, and (2) emissions accounting and forecasting—for example, as used to track progress toward achieving state goals for reducing greenhouse gas emissions. A limited number of top-down evaluations and pilot studies have been performed. Perhaps the most current were prepared in 2015 as part of a multi-year initiative designed to assess the utility of top-down modeling as a viable technique for evaluating energy efficiency programs in Massachusetts.[24] These evaluations showed promising potential but also indicated that more effort is required to refine analysis tools and improve access to data.[25]

7.7.3.2 *EM&V 2.0*

EM&V 2.0 is catchall term for recent advances in metering, data availability, and analytical tools associated with documenting the energy and demand savings from specific energy efficiency measures or projects. EM&V 2.0 involves applying these advances to program evaluations. One rapidly developing area of EM&V 2.0 is automated M&V (auto-M&V), which can use a combination of automated data collection (e.g., 15-minute, hourly, or monthly energy data and corresponding temperature data) and processing, machine learning, and open-source or "black-box" analytical tools to calculate savings at a site or at the program level. These tools use independent variable data that can be readily obtained (e.g., ambient temperatures and time of day, day of week, season). This is similar to energy billing analyses that have been conducted for decades, but using richer data sets and better analytics.

Another developing field is behavioral analytics, which involves drawing insights from high-frequency, human-focused data that reflect how people behave—for example, data that indicate how much energy people are consuming on an hourly basis, thus indicating which appliances they are using. This kind of analysis has the potential to provide tremendous value to a wide range of energy programs. For example, using highly disaggregated and heterogeneous information about actual energy use, program implementers may be able to target specialized energy efficiency or demand response programs to specific households, conduct EM&V of programs on a much shorter time horizon than previously possible, and provide better insights into the energy and peak-hour savings associated with specific types of energy efficiency and demand response programs (e.g., behavior-based programs).[26]

EM&V 2.0 Methods and Data Collection Tools

M&V 2.0 is formally defined as *"The leveraging of smart grid investments, advances in interval meter data, nonintrusive load monitoring, and equipment-embedded sensors and controls to provide new tools with potential to reduce the cost of M&V, produce more timely results with higher confidence and transparency, and thereby increase the acceptance of the savings calculations."** These concepts have been further applied to evaluation to create another term—EM&V 2.0.[**]

Examples of EM&V 2.0 methods and data collection tools include the following:

- "Big Data" analytics **-** process of examining large quantities of data to uncover hidden patterns, unknown correlations and other useful information that can be used to make better decisions
- Automated M&V – calculating savings without direct human interaction
- Behavior analytics **-** providing insights into how people make energy decisions
- Benchmarking **-** measuring a building's energy use and then comparing it to the average for similar buildings, to allow owners and occupants to understand their building's relative energy performance and help identify opportunities to cut energy waste
- Smart meters and advanced metering infrastructure (AMI) – utilizing short time frame interval meter data
- Smart devices—e.g., thermostats, appliances and energy management systems
- Wireless metering – utilizing transducers that do not need to be connected to monitoring stations via wires
- Non-intrusive load metering **-** analyzing changes in the voltage and current going into a building or the run times of in-house systems, and deducing what appliances or equipment are in use and measuring their energy consumption

References:

- Jessica Granderson, Samir Touzani, Claudine Custodio, Michael Sohn, Samuel Fernandes, and David Jump, *Assessment of Automated Measurement and Verification (M&V) Methods*, Lawrence Berkeley National Laboratory, July 2015, LBNL-187225, 5.

** Tom Eckman, "EM&V 2.0 – New Tools for Measuring Energy Efficiency Program Savings," Electric Light & Power Newsletter, February 2014, http://www.elp.com/Electric-Light-Power-Newsletter/articles/2014/02/em-v-2-0-new-tools-for-measuring-energy-efficiency-program-savings.html.

The potential benefits of (E)M&V 2.0, particularly with auto-M&V, include the following:

- The time period for analyses can be reduced from the typical 9 to 12 months of pre- and post-project implementation data to as little as just a few weeks of data collection and analyses to reliably determine savings, making results available faster.[a]
- The overall cost of (E)M&V will be lower, which reduces a barrier to investment in efficiency by consumers and utilities.
- More standardized analytics will enable a strongly constructed, reliable calculation-checking process.

In the future, determining energy and demand savings from efficiency programs has the potential to be dramatically different than the current paradigm because of smart grid investments, combined with other technological advances in residential interval meter data, nonintrusive load monitoring, and

[a] A recently released research report reviews the efficacy of short-term metering: ASHRAE RP-1404, http://www.techstreet.com/products/1872406.

equipment-embedded sensors and controls that will give evaluators new tools with the potential to reduce the cost of EM&V, produce more timely results, and increase the acceptance of the savings calculations.[27]

Two recent papers reviewed key trends in the changing EM&V paradigm and the implications new industry developments have on current and future EM&V practices and activities:

- From the American Council for an Energy-Efficient Economy (ACEEE): "The energy efficiency sector has long sought the ability to measure energy savings as they happen. While this has not been fully realized, we are getting closer. ICT [Information and Communications Technologies] is simplifying the harvesting of savings data, improving the quality of analysis, and increasing the timeliness of reporting. All of these features improve energy efficiency programs and enable energy efficiency markets. By extension, they contribute to greater energy savings throughout the economy."[28]
- From the Regional Evaluation, Measurement, and Verification Forum: "Advanced data collection and analysis tools and systems offer new opportunities for understanding and engaging customers, offering value to project and program delivery as well as to evaluation…. There remain important evaluation challenges that are not solved by greater volumes or frequency of consumption data, or higher speeds of data processing."[29]

There are several challenges associated with EM&V 2.0, including the current limited availability of high-resolution data (many jurisdictions do not have AMI data) and, to date, the simple lack of experience with the application of (E)M&V 2.0 (as mentioned below). However, one particularly important possible concern is that currently automated EM&V, and EM&V 2.0 in general, only determine gross savings metrics based on baselines that are pre-project, existing conditions. These methods do not provide savings relative to standard efficiency equipment (e.g., building energy codes, equipment standards, or common practice), considered net savings under some scenarios. Nor do these methods address attribution of savings. As noted by the above-referenced ACEEE paper, attribution of savings (net savings, see discussion below) and other issues require further efforts by the efficiency industry: "The policy challenges of net versus gross savings will not go away with the addition of ICT. And issues related to data ownership, access, privacy, and security are likely to persist for a while. Other policy issues include the need for agreement on confidence levels, recovery of ICT infrastructure costs, and standardization of EM&V protocols across service territories and state lines."[30]

In some cases, these EM&V 2.0 advances may already be incorporated into current EM&V practices. However, specific EM&V 2.0 pilots and examples are difficult to identify.[31] One example is the evaluation of the PowerStream (a Canadian utility) Advanced Power Pricing pilot, a technology-enabled variable peak-pricing pilot program.[a] Evaluation of the program relies on interval data from all participants, but also from all eligible non-participants. Nonparticipant interval data over a two- to three-year period is being used to develop the set of control customers to be used, based on the matching of intra-daily, day-type specific load profiles. The evaluation (currently in progress) is leveraging thermostat-collected data to segment participants and improve estimated impact precision. Outputs include automated plotting of load profiles across a large number of cross-sectional elements of every summer day.[32]

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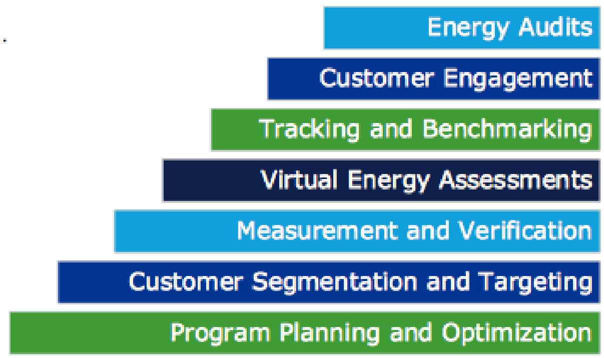
[a] Generally, variable peak pricing is a hybrid of standard time-of-use and real-time pricing. The peak period is defined in advance, but the price established for the on-peak period varies by system or market conditions.

A number of companies offer auto-M&V products for administrators of energy efficiency and demand response programs operated by utilities or third-party administrators, primarily under the SaaS model—a software licensing and delivery model in which software is licensed on a subscription basis and is centrally hosted. Figure 7.40 indicates typical service offerings for auto-M&V.

Figure 7.40. Typical service offerings of auto-M&V SaaS vendors[33]



7.7.3.3 *Assessing Non-Energy Impacts*

Beyond energy and demand savings, there are a number of impacts associated with energy efficiency and DER programs that are commonly called *non-energy benefits* or, perhaps more accurately, *non-energy impacts* because these impacts can be positive or negative. Non-energy impacts can be categorized as those accruing to the utility system, society as a whole, and individual participants.[34] Some research indicates that the value of benefits to society as a whole and individual participants make up the bulk of the value of non-energy impacts (versus utility system non-energy benefits).[35 36]

Examples include reduced air emissions and other environmental benefits, productivity improvements, health benefits such as reduced asthma cases, jobs created and local economic development, reduced utility customer disconnects, greater comfort for building occupants, lower maintenance costs due to better equipment or, conversely, increased maintenance costs due to new and more complex systems. Another benefit of energy efficiency programs, which could be considered either an energy or non-energy benefit, is demand reduction-induced price effects (DRIPE). This element is the potential monetary benefit to all electric consumers that comes from reduced demand for electricity.[37]
Several states are now including non-energy impacts in their evaluations of energy efficiency programs funded by utility customers, but not many. In particular for cost-effectiveness analyses, the ACEEE 2012 review of evaluation practices indicated the following:[38]

> *.... while 36 states (including all the states with TRC [total resource cost] as their primary [cost-effectiveness] test) treated "participant costs" for the energy efficiency measures as a cost, only 12 states treated any type of participant "non-energy benefits" as a benefit.... [M]ost of those "non-energy" participant benefits were confined to "water and other fuel savings." Only 2 states quantified a benefit for "participant O&M savings" and none quantified any benefits for things like "comfort," "health," "safety," or "improved productivity" in their primary benefit-cost test.*

Not assigning a value to these non-energy impacts, assuming they are positive, can result in negative bias in energy efficiency and DER program investment decisions and less than fully effective program participation, designs, and marketing (if program implementers do not focus on the same benefits that participants focus on).

Also, while this discussion has primarily focused on energy efficiency activities, DERs also have non-energy impacts. The primary ones may be utility system benefits such as improved reliability and support for renewable resources integration through demand response and storage. Given the potential significant value of non-energy impacts, it is possible that more jurisdictions will analyze these impacts in the future and take them into consideration in cost-effectiveness analyses, such as in the societal cost test.[39] This may in turn create new metrics and the need for EM&V approaches that provide the values associated with these metrics.

Reduced air emissions associated with the production of electricity and thermal energy from fossil fuels is an important non-energy impact of energy efficiency. Historically, emission reductions from energy efficiency and DER activities were usually only described subjectively in program evaluations as a non-quantified (non-monetized) benefit. This is changing for at least two purposes: (1) to improve cost-effectiveness evaluation of energy efficiency and DER programs by monetizing their environmental benefits, and (2) to support state claims of emissions benefits in state air pollution plans (e.g., State Implementation Plans).

Energy Efficiency, DERs, and Avoided Air Emissions in a Capped Emissions Regulatory Structure

The *level* of the cap is an important aspect of an emissions cap (or cap-and-trade) program. In general, emissions may not exceed the cap, and they are also unlikely to be below the cap during any substantial period of time. The fact that capped emissions tend to remain at the cap level is relevant to the effect of energy efficiency in particular (as well as some DER activities). This is because reductions in the emissions of electricity generators do not alter the overall cap on emissions from all electricity generators. That means that freed-up emission allowances, due to the impact of energy efficiency and DERs on generators, can be sold in the market and used elsewhere or banked for use in a later year, such that total emissions will remain roughly equal to the cap level. While energy efficiency does not result in greater emission reductions than are specified by the cap, energy efficiency has been shown to be a very cost-effective way to meet the emissions cap.

Development of market mechanisms that create monetary value for energy efficiency and related environmental benefits has been a long-term goal of the energy efficiency industry.

Energy efficiency set-asides for programs such as the Acid Rain Program and the NO_x SIP Call[40] provided such opportunities, although the uptake of activity was relatively low, in part due to the transaction costs and uncertainty associated with the EM&V. New regulations, such as the CPP, provide a new opportunity which may catalyze new energy efficiency activity because the CPP specifically calls out demand-side energy efficiency as a strategy for meeting the requirements of the CPP.[41] The EPA also has provided guidance for energy efficiency EM&V in the CPP documents that support industry standard best practices, while also acknowledging—and even encouraging—further advances in EM&V practices.[42]

For any type of energy efficiency program, the avoided air emissions are determined by comparing the emissions occurring after the program is implemented to an estimate of what the emissions would have been in the absence of the program (i.e., emissions under a baseline scenario). Conceptually, avoided emissions are estimated using energy savings calculated and one of two approaches:[43] [a]

- Emission factor approach—This approach involves multiplying energy savings by emission factors (e.g., pounds of carbon dioxide [CO_2] per megawatt-hour) representing characteristics of displaced emission sources to compute hourly, monthly, or annual avoided emission values (e.g., tons of CO_2 per year). There are several sources of emission factors and approaches for calculating the factors.
- Scenario analysis approach—This approach involves calculating a modeling Side Case of source (e.g., electricity generating units connected to a grid) emissions without the energy efficiency or DER programs and comparing that with the emissions of those sources operating with the reduced energy consumption associated with the programs. This approach represents an attempt to get a more accurate picture of what emissions are avoided by the actual energy use reductions from the efficiency and DER programs, based on when those reductions occur and what generation sources would have been used to meet the higher load in the Side Case. Emerging metering technologies and analytical tools are able to provide insight into the specific time of day, week, or year energy savings are occurring, which can reduce the cost and uncertainty level of this approach.

7.7.4 EM&V Barriers, and the Policies, Programs and Regulations That Address Them

Ensuring that EM&V plays an effective supporting role for energy efficiency and DER activities has become increasingly important as these activities have changed and expanded. In particular, interest in data-driven policies and regulations, as well as data-driven consumer investment decision-making, places increasing importance on EM&V—the source of energy efficiency and DER performance data. An overall issue in providing these data is whether EM&V is keeping up with evolving energy efficiency and DER activities and supporting greater deployment and the associated positive impacts. This section briefly describes two fundamental barriers associated with EM&V for energy efficiency and demand response, both related to the fact that savings determinations are estimates:

- The dilemma of balancing rigor with cost—i.e., how to find the right balance of impact assessment integrity and cost of implementation, and the ramifications if transaction costs are so high that they discourage appropriate energy efficiency and DER activities
- Defining appropriate baselines, the counterfactual of EM&V.

7.7.4.1 *Assessing Costs Versus Benefits of Increased EM&V Rigor*[44]

Because the results from impact evaluations of energy efficiency and demand response are estimates,[b] their use as a basis for decision-making can be challenged if their sources and level of accuracy are not described. Minimizing uncertainty and balancing evaluation costs with the value of the evaluation information leads to perhaps the most fundamental evaluation question: "How good is good enough?" This question is a short version of asking: (1) what level of certainty is required for energy savings

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[a] The timing of any displaced electricity production, as well as the location of the displaced generation, can affect the amount and type of avoided emissions.

[b] Impacts from distributed generation and storage are usually directly measured and are not considered estimates. Common industry practice for EM&V for these resources does not use counterfactuals; the resources' impact is determined by measuring output.

estimates resulting from evaluation activities, and (2) is that level of certainty properly balanced against the amount of effort (e.g., resources, time, money) used to obtain that level of certainty?

An important principle associated with addressing “how good is good enough?” is that evaluation investments should consider risk management principles and thus balance the costs of evaluation against the value of the information derived from evaluation (i.e., evaluation also should be cost-effective). The value of the information is directly related to the risks of underestimating or overestimating the benefits (e.g., demand and energy savings) and costs associated with efficiency investments. These risks might be associated with errors of commission or errors of omission. An error of commission might be overestimating savings, which in turn can result in continuing programs that are not cost-effective or overpaying contractors, program administrators, and participants. An error of omission, on the other hand, might be associated with underestimating savings or not implementing efficiency actions because of the difficulty in documenting savings, both of which can result in underinvesting in energy efficiency and DERs and relying on other energy resources that have their own risks and uncertainties.

7.7.4.2 *Baselines*

A major complexity of impact evaluation is defining the baseline. *Baselines* are the conditions, including energy consumption and demand, which would have occurred without implementation of the subject energy efficiency activity. Baselines can also include definitions of non-energy metrics that are being evaluated, such as air emissions and jobs.[45] Theoretically, the true energy (or demand) savings from an energy efficiency (or demand response) program are the difference between the amount of energy (or demand) that participants in a program or a project use relative to the amount of energy (or demand) that those same participants would have used had they not been in the program or implemented the project during the same time period—the counterfactual scenario. However, we can never observe how much energy those participants would have used had they not been in the program or project.[46] Developing baselines is complicated by the widespread confusion about the difference between a baseline (what would have happened in the absence of the measure) and attribution (what would have happened in the absence of the program).

Selecting an appropriate baseline is both complex and often difficult, but it is fundamental to determining the validity of EM&V results. With control group approaches, the baseline is defined by the characteristics and energy use of the control group(s). Ideally the control group is selected using randomized control trial methods, but in practice control groups are often selected using quasi-experimental methods that less reliably define a baseline scenario. For impact evaluation approaches that do not rely on control groups (deemed savings and M&V), baseline definitions are determined by the type of project being implemented, site-specific issues, and broader, policy-oriented considerations. These considerations usually result in one of three different types of baselines: (1) existing conditions, (2) building energy codes and appliance and equipment standards (C&S), and (3) common practice (which can incorporate both existing conditions and C&S baseline assumptions).

7.7.4.3 *Policies, Programs, and Regulations That Address These Barriers*

With regard to balancing EM&V rigor with costs, as noted above, the evaluation process should consider risk management principles and thus balance the costs and value of information derived from evaluation. *Impact evaluation is thus about managing risk.* Conceptual approaches that draw upon risk management techniques provide a useful structure for addressing evaluation issues. Unfortunately for energy efficiency and demand response in particular, risk management is hampered by the large number of difficult-to-quantify aspects of evaluation, although the tools for addressing these difficulties are improving. Supply-side resources have uncertainty and risks as well (e.g., uncertainties associated with future fuel costs). However, perhaps the single most identifiable risk of efficiency is the inability to directly measure savings, which creates uncertainty.

To address these uncertainties and risks, current public policy approaches usually involve setting what those involved consider to be a reasonable budget first, and then relying on professional judgment of the EM&V professionals to find EM&V approaches that match that budget. However, ideally, there would be an iterative process of comparing budgets with savings certainty and achieving program goals (which can include requirements for process and market evaluations) and then having policy makers or regulators determine whether such a level of savings and program goal achievement certainty is sufficient. The research gaps section of this appendix identifies a need to improve on this current practice.

With regard to baselines, for private sector transactions—for example, between an ESCO and an industrial customer—the baseline is typically defined as the existing conditions prior to the energy efficiency or DER project implementation. As discussed in Key Findings and Insights near the beginning of this appendix, consumers tend to want to know what the savings are compared to actual past energy bills, not hypothetical bills.

However, determining baselines is different for public policies. Table 7.13 summarizes standard industry practice for determining baselines by program category. Note that these are not mandates; each jurisdiction and each program should establish its own baseline scenarios. For utility programs, the guidance for baseline definitions is typically set in regulation or implementation guidance, such as an EM&V framework. However, in at least one case, for California, the baseline issue has been addressed in legislation.[47]

Table 7.13. Standard Practices for Selection of Baselines for Common Program Categories[48]

PROGRAM CATEGORY FOR PURPOSES OF BASELINE DETERMINATION	EXISTING CONDITIONS BASELINE	CODES AND STANDARDS BASELINE	COMMON PRACTICE BASELINE
Early replacement or retrofit of functional equipment still within its current useful life Process improvements	X Existing conditions baseline for the remaining life of the replaced equipment or process	X C&S baseline for the time period after the remaining life of the replaced equipment	X Common practice baseline for the time period after the remaining life of the equipment
Replacement of functional equipment beyond its rated useful life		X	X
Unplanned replacement for (of) failed equipment		X	X
New construction and substantial existing building improvements		X	X
Non-equipment based programs (e.g., behavior-based and training programs)			X What people in a control group would be doing in the absence of the program

7.7.5 Research Gaps

In June 2014, the Energy Efficiency Standardization Coordination Collaborative of the American National Standards Institute (ANSI) completed a guidance document, *Standardization Roadmap: Energy Efficiency in the Built Environment.* The roadmap defines several aspects of EM&V with gap analyses.[49] Table 7.14 summarizes the EM&V aspects and identified gaps from that effort. More definitive descriptions and information are in the referenced report. The ANSI report also identifies the energy efficiency industry's need for workforce credentialing, including in the area of EM&V.

Table 7.14. ANSI-Identified EM&V Aspects and Gaps[50]

EM&V Aspect	Gaps
Baselines	Support for defining existing conditions and common practice baselines, treatment of dual baselines, industrial baselines, non-direct dependence on production levels, and automatic benchmarking of commercial and residential buildings
Methods for determining annual savings	Addressing potential inconsistent savings estimates associated with the use of standardized documentation, different methods, and assumptions through methods to compare results
Calibrated computer simulation used for M&V	Standardization of calibration
Statistical M&V methods	Quantification of uncertainty in regression and computer simulation models, and standardized and general reporting of uncertainty
Whole-building metered analysis	Standards for data collection and analyses, statistical approaches using high-resolution data and automated analyses
Methods for large complex projects	Guidance on projects with heterogeneous measures and on how to present results for such projects
Effective useful life (EUL)	Guidance on the treatment of EULs
Technical reference manuals (TRMs)	Establishing standard formats and content
Reporting and tracking systems	Support for a standard set of terms and definitions, and standardized data collection and reporting, including addressing central data needs and standard savings definitions and program typologies
Top-down evaluation	Support for building a consistent approach to top-down analyses
Evaluation in financial analyses	Support for developing a systematic framework for analyzing parametric uncertainty of efficiency projects and programs, q framework for translating engineering uncertainties into financial instrument ratings, and q stakeholder process to assess needs
Conformity assessment/accreditation	Established relationship between conformity assessment standards that impact energy efficiency, including impact in risk and financial management

The following subsections briefly discuss particular research issues, including those identified in Table 7.14 and others identified based on current EM&V practices and trends as noted earlier in this appendix. All of these data gaps are associated with the need for higher quality and more readily available energy efficiency and DER data to assess energy and non-energy impacts and prioritize and support appropriate investments in these electricity resources.

7.7.5.1 *Reliability and Certainty of Evaluated Impacts*

A significant challenge in evaluating energy efficiency and demand response programs is defining the reliability and certainty of energy and demand savings estimates. While EM&V seeks to determine energy and demand savings reliably and with reasonable accuracy, the value of the estimates as a basis for decision-making can be called into question if the sources and uncertainty level of reported savings estimates are not understood and described. While additional investment in the estimation process can reduce uncertainty, trade-offs between evaluation costs and reductions in uncertainty are inevitably required. Thus, improved accuracy (and associated EM&V costs) should be justified by the value of the improved information. Improved methods for defining and reporting metric reliability and certainty can increase understanding and confidence in energy efficiency and demand response benefits. This would also be helpful for a more structured, risk-management approach to setting EM&V budgets (as discussed in the prior section).

7.7.5.2 *Input Data Access and Availability Needs*

The availability of large amounts of reliable and short-time interval data have supported improvements in EM&V, as described earlier in this appendix. However, these big energy data sets are not necessarily all the information needed. Beyond energy use and temperature data that are potentially or already readily available are information needs related to:

1. Reliable data at the same level of granularity as the energy use data that may be necessary for accurately determining energy savings (examples of matching independent variable data are occupancy information, plug load data, and building temperature set-points)
2. Explanatory data (sometimes called thick data)[51] that may be necessary to describe the *why* of equipment and human performance—and thus the observed impacts

With respect to data availability, consumer preference, security, and privacy are issues that continue to arise and must be addressed before widespread use of data can be assured. However, these issues seem to be surmountable. For example, on January 12, 2015, President Obama announced the release of the final concepts and principles for a Voluntary Code of Conduct (VCC) related to the privacy of customer energy usage data for utilities and third parties.[52] In addition, individual states have established policies and regulations associated with protection of consumer energy data.[53]

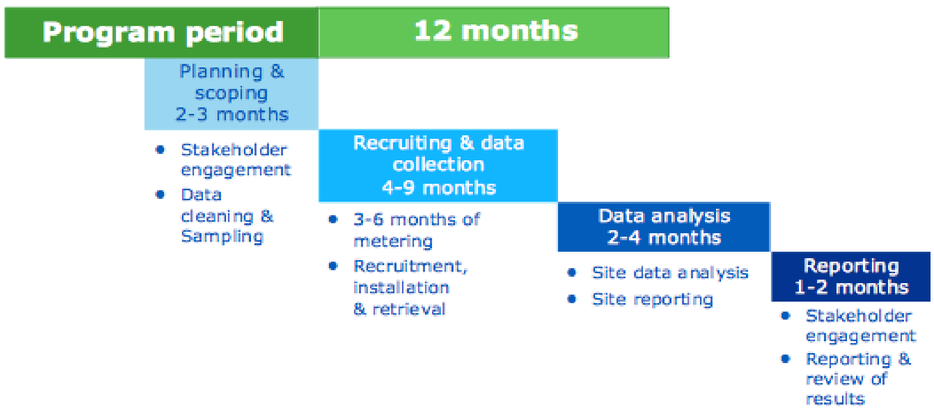
7.7.5.3 *Consistent Reporting and Program Typologies*

A number of studies have noted that reporting of the savings and costs of energy efficiency (and DER) actions varies in comprehensiveness, transparency, and rigor.[54] Furthermore, other research on energy efficiency programs funded by utility customers has found that program data are often not defined and reported consistently among states. Specifically, three key concerns were found in compiling and analyzing program information on a regional or national basis, some of which could be addressed by the common typology and standardized definitions: (1) savings and program costs are not defined consistently, (2) program data are not reported consistently across states, and (3) programs and market sectors are not characterized in a standardized fashion.[55] Thus, efforts to better standardize EM&V-related terms, data taxonomy, data dictionaries, and communication specifications are needed to enable more consistent ("apples to apples") comparisons and meaningful summation of results from different activities and jurisdictions. Such efforts could also promote better understanding of the uncertainty around savings measurements.

7.7.5.4 *Timeliness of EM&V Reporting and Utilization*

Delays in obtaining evaluation results from energy efficiency programs have been an ongoing issue for decades. While this problem has been less of an issue for non-utility energy efficiency programs and DER technologies with more readily available data (e.g., distributed generation) or shorter time periods of interest (e.g., demand response), the typical time required to organize evaluations, gather sufficient amounts of data, and analyze and summarize the data is 9 to 18 months from the end of a program cycle to the delivery of impact evaluation results (Figure 7.41.) for utility customer-funded efficiency programs. Approaches relying heavily on deemed savings and simple project verification tend to require less time compared to approaches that require extensive data collection over a wide range of operating conditions (e.g., different seasons), such as control group and M&V approaches. Better planning and EM&V 2.0 approaches may have the potential to reduce these time frames and make EM&V information more readily valuable.

Figure 7.41. Typical timeframe for utility energy efficiency program impact evaluation process[56]



7.7.5.5 *EM&V Factors: Attribution of Savings, Measure Lifetime and Persistence of Savings, and Rebound*

Following is a discussion of development needs for three key EM&V factors: attribution determination, measure lifetime quantification, and "rebound effect" assessment.

Attribution determination—assessing net savings—involves separating out the energy efficiency and DER impacts that are a result of influences other than the program being evaluated, such as consumer self-motivation or effects of other programs. Given the range of influences on consumers' energy consumption—and the complexity in separating out both short-term and long-term market effects caused by the subject programs (and other programs)—attributing changes to one cause (e.g., a particular program) can be quite complex. This issue is compounded by a lack of consensus by policymakers and regulators as to which market influences and effects should be considered when determining net savings and the role of net savings in program design, implementation, and "crediting" of savings to program administrators.[57] While the importance of net savings in the future will depend at least in part upon the type of energy efficiency programs implemented and whether baselines defined as common practice become standard practice, further improvements in attribution assessment methods, definitions, and reporting will be helpful.

Energy efficiency measure lifetime is critical to estimating total or lifecycle benefits, calculating cost-effectiveness, and prioritizing long-term versus short-term investments in energy efficiency and DERs. Estimates of lifetime savings also impact load forecasts, estimation of savings potential, the setting of performance incentives for program administrators, recovery of lost revenue for utilities, and avoided emissions estimates. Better understanding and quantification of the variability of savings over time (persistence) also may be important for at least a subset of energy efficiency actions, measures, or programs, including some that are emerging or envisioned as significant sources of savings. However, research has found that savings lifetimes may vary significantly within a program category. While some of this variability is justified on technical grounds, savings lifetimes and persistence can also vary for reasons that may be less accurate or justified, such as different definitions, differing engineering assumptions, or different levels of rigor in EM&V.[58] Improving the quantification of measure lifetimes and understanding of persistence may provide more reliable estimates of savings from energy efficiency activities and potential cost-effectiveness of investment in energy efficiency resources.

The "rebound effect" pertains to the economic responses of consumers, firms, and ultimately the overall economy to policies and programs that promote end-use energy efficiency. Rebound has long been a controversial topic in energy efficiency impact and potential analyses, policies, and budgets. It is receiving renewed attention as energy efficiency is increasingly considered as a means of large-scale abatement of greenhouse gas emissions. Overall, the literature indicates that there is considerable uncertainty regarding the magnitude of the rebound effect. Empirical estimates of the "microeconomic rebound"—i.e., at the level of consumers, households, and firms—are consistently positive (non-zero and implying a partial offset to absolute energy consumption savings from policies and programs predicted by standard engineering calculations). In particular, there is little or no evidence of microeconomic "backfire," the conjectured phenomenon of rebound more than offsetting efficiency gains. At the same time, rebound yields an economic benefit by allowing consumers' and firms' increased consumption of energy services and other goods and services. Uncertainty regarding the magnitude of the economy-wide rebound is even greater, and considerable caution is needed in interpreting and applying quantitative estimates from the literature, indicating that further research would be valuable.

7.7.5.6 *EM&V Practitioner Training, Certification, and Independence*

A relatively small, yet vibrant, industry of professionals is involved in EM&V, including:

- Professional consultants hired to conduct potential studies, impact, process, and market evaluations. Specifically, for EM&V activities, these consultants can fulfill the role of independent, third parties providing *evaluated savings* values.
- Staff within utilities and ESCOs, and other program administrators and implementers (including some large manufacturing firms and institutions that are consumers), who may conduct the same type of analyses as the EM&V consultants, but with focus on claimed savings and performance tracking for internal business purposes.

Expanding programs for energy efficiency and DERs, along with advances in EM&V—particularly with greater use of sophisticated data analysis tools and use of "smart" technologies—is driving increased interest in professional EM&V training and certification. Certifying EM&V professionals could lead to more energy efficiency and DERs because funders, regulators, policy-makers, utilities, and consumers may have more confidence in the savings determination. A recent ANSI cross-sector effort, the Energy Efficiency Standardization Coordination Collaborative, developed roadmaps on a number of energy efficiency topics, including workforce credentialing. The document notes that "…unsubstantiated claims of competency and inconsistent assessment practices have given rise to a confusing and rather chaotic assortment of workforce credentials. The good news is that a core of quality standards and credentialing schemes are in place and provide a strong launching pad from which to build a competent workforce. The challenge is sorting through the various credentials offered…."[59]

The only directly related EM&V certification is the Efficiency Valuation Organization's (EVO) Certified Measurement & Verification Professional (CMVP) designation.[a] [60] There are approximately 4,000 designated CMVPs professionals worldwide, with about 1,000 of those in the United States.[61] The training is focused on project M&V and not program evaluation. Other organizations such as the International Energy Program Evaluation Conference, EPA, and the Association of Energy Services Professionals offer education on energy efficiency evaluation. DOE has also sponsored a study to investigate the development of a certification for evaluators of energy efficiency program impacts. Another topic related to EM&V professionals is independence. There are no formal or universally agreed to definitions of independent or third-party evaluators and no well-established precedents as to who hires the entities that provide the evaluated savings reports. For utility programs, for example, the hiring entity could be the utility regulator, the program administrator, or perhaps some other entity. However, in general practice, "independent third party" means that the evaluator has no financial stake in the evaluation results (e.g., magnitude of savings) and that its organization, its contracts, and its business relationships do not create bias in favor of, or opposed to, the interests of the program administrator, implementers, participants, utility customers, or other stakeholders. State regulatory bodies have taken a variety of approaches to: (1) defining the requirements for evaluators who are asked to review the claimed savings and prepare evaluated savings reports, and (2) deciding who hires that evaluator.[62] This area has gained increased interest as the topic and requirement for independent verifiers is indicated in the CPP.[63]

7.7.5.7 *Opportunities for Further Development of EM&V Methods: Deemed Savings, Randomized Control Trials, EM&V 2.0, and Top-Down Evaluation*

The following are discussions of four EM&V methods where development needs have been identified: Deemed savings can be integral to reliable and cost-effective EM&V. However, deemed savings values must be developed and used correctly (e.g., values are applied only where they are applicable). Reviews of deemed savings values and their documentation have raised concerns with consistency in methods and assumptions used to develop values, transparency, clarity, and accuracy.[64] More resources and standardization in the development and application of deemed savings could increase their use. CPP documents provide examples of criteria that could support such enhancements.[65]

Randomized control trials (RCTs) are considered to be the gold standard for documenting energy savings from energy efficiency programs. The statistical validity of more conventional approaches and EM&V 2.0 approaches, as compared to RCTs, has not been rigorously tested. Some studies have shown that alternative methods do not produce energy savings estimates that are similar to those of an RCT.[66] However, RCTs themselves have limitations related to both methodology and pragmatic concerns. These include but are not limited to population availability, data contamination, time for follow-up, external validity, cost, ethics, informed consent, and the inhibition of innovative research questions.[67] Applying practices in the broader field of statistics and econometrics may help support further development of RCTs for energy efficiency and DER programs, as well as for analyses used in EM&V 2.0.

EM&V 2.0, including auto-M&V, are fields with significant potential for improving confidence in the performance of energy efficiency and DER technologies. Diverse industry stakeholder groups have

[a] "EVO offers worldwide the Certified Measurement & Verification Professional (CMVP) designation. The right to use the CMVP title is granted to those who demonstrate proficiency in the M&V field by passing a four-hour written exam and meeting the required academic and practical qualifications. EVO's certification level training is offered as preparation for the exam and as a review of basic principles for experts."

expressed interest and engagement in the topics of streamlining the M&V process, leveraging automation and emerging analytics tools, and validating whole-building approaches to M&V. Further research is needed on validating energy savings predictions and the automated tools that develop such savings.[68 69]

Top-down evaluation is an EM&V approach that shows promise but has not been used, or even piloted, in many applications. However, as data availability increases, analysis standards should also progress. Opportunities to advance top-down evaluation include guidance documents that could improve the reliability of top-down evaluation results; coordination among entities applying or considering top-down evaluation; additional, rigorous top-down pilot evaluations and research; efforts to increase consistency in top-down evaluation terminology; and governmental efforts to help improve the quality and availability of the underlying data used in top-down evaluations.[70]

7.7.5.8 *EM&V for Transmission and Distribution (T&D) System Efficiency*

Transmission and distribution efficiency is an area of growing interest, and while EM&V is conceptually straightforward, in practice it can be complicated (and thus expensive in some cases) to determine reliable energy savings values. While T&D EM&V practices are a work in progress, EM&V for conservation voltage reduction and voltage optimization is more advanced, with several ongoing efforts to both develop protocols and evaluate programs. Further development of T&D EM&V methods would support initiatives to increase electricity savings within the T&D system.

7.7.5.9 *EM&V for Codes and Standards*

As noted earlier in this appendix, ex-ante estimates of building code impacts are common, whereas ex-post evaluation and determination of energy savings from building energy code adoption and compliance activities are not as well established. Given their importance as energy and demand savings strategies, further development of EM&V methods and encouragement of ex-post evaluations documenting impacts and lessons learned would support initiatives to strengthen codes and standards.

7.7.5.10 *EM&V for Financing Programs*

Utility customer–supported financing programs are receiving increased attention as a strategy for achieving energy saving goals. These financing programs have unique aspects that may create challenges in adapting traditional evaluation approaches for assessing their impacts, cost-effectiveness, and efficacy. Many consumers can finance energy efficiency projects using private options. Thus, it is important for evaluations to focus on what savings attributed to financing are truly “additional” or would have occurred even in the absence of a utility customer-funded program.

As noted in a recent report,[71] the most promising methods for assessing the impacts of energy efficiency financing are a matter of some discussion within the evaluation community. More research and field experience may be needed before best practices can be established. In particular, development of cost-effective methodologies for estimating savings that are attributable to financing efforts is needed. Data collection, including surveying methods specific to efficiency financing, require further definition as part of such methodologies. Guidance also is needed on effective experimental and quasi-experimental study designs. In addition, more research is needed on program logic models for efficiency financing programs that seek to transform markets and metrics that are appropriate for measuring progress.

7.7.5.11 *EM&V for Non-Energy Impacts*

Over at least the last 20 years, the non-energy impacts of energy efficiency and DERs have been subjected to research, development, and application of EM&V methodologies, and use in various cost-effectiveness tests.[72] This experience has helped to change stakeholders' perception of non-energy impacts from one of general unfamiliarity and skepticism to acknowledgement that some non-energy impacts—particularly benefits—are important to understand, measureable, and critical to increasing the uptake of energy efficiency and DERs. However, additional effort is needed to further develop more robust methods for assessing each of the categories of non-energy impacts identified in Section 7.8.4.3: utility systems (e.g., power quality, substation infrastructure), society as a whole (e.g., water infrastructure, jobs), and individual participants (e.g., enhanced productivity, health). Related to improving these methods is the need to develop improved confidence in applying non-energy impacts in cost-effectiveness analyses as well as capacity building in terms of increased communication of such impacts and additional, trained professionals to assess the impacts.

References

[1] Steven R. Schiller. *Energy Efficiency Program Impact Evaluation Guide*. p.xiv. SEE Action (State and Local Energy Efficiency Action Network). 2012. https://www4.eere.energy.gov/seeaction/publication/energy-efficiency-program-impact-evaluation-guide.
[2] Steven R. Schiller. *Energy Efficiency Program Impact Evaluation Guide*. Appendix A. SEE Action (State and Local Energy Efficiency Action Network). 2012. https://www4.eere.energy.gov/seeaction/publication/energy-efficiency-program-impact-evaluation-guide.
[3] California Assembly Bill No. 802. Energy Efficiency. AB-802. 2015 (approved October 8. 2015). https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201520160AB802.
[4] International Energy Agency. *Welcome to IEA Demand Side Management Energy Efficiency*. http://www.ieadsm.org. Accessed February 25, 2016.
[5] Independent System Operator – New England. *ISO-NE Measurement and Verification of Demand Reduction Value from Demand Resources, Revision 6*. June 1, 2014. http://www.iso-ne.com/participate/rules-procedures/manuals; PJM Forward Market Operations. *PJM Manual 18B: Energy Efficiency Measurement & Verification*, *Revision 2*. 2015. https://www.pjm.com/~/media/documents/manuals/m18b.ashx.
[6] U.S. Department of Energy. *Building Energy Codes Program Resource Center*. http://www.energycodes.gov/resource-center. Accessed March 3, 2016; Personal communication with Ralph Prahl. April 16, 2016.
[7] Allen Lee, Dan Groshans, Peter Schaffer, Alexandra Rekkas, Richard Faesy, Lynn Hoefgen, and Phil Mosenthal, *Attributing Building Energy Code Savings to Energy Efficiency Programs*, Portland, OR: The Cadmus Group, Inc., 2013. http://www.imt.org/uploads/resources/files/NEEP_IMT_IEE_Codes_Attribution_Final_Report_02_16_2013.pdf.
[8] Allen Lee, Linda Dethman, Christy Gurin, Doug Burns, Suzanne (Phi) Filerman, David Thomley, and Stephanie Collins, *Statewide Codes and Standards Program Impact Evaluation Report for Program Years 2010–2012*, The Cadmus Group, Inc., Energy Services Division, for CPUC (California Public Utilities Commission), 2014, CPUC Study ID 1038/CALMAC Study ID SCE0319.01, http://www.calmac.org/publications/SCE-PG%26E_C%26S_Process_Evaluation_FINAL_5-28-12.pdf.
[9] U.S. Department of Energy. *Building Energy Codes Program - Funding Opportunity*. https://www.energycodes.gov/funding-opportunity-doe-building-energy-codes-program-strategies-increase-residential-building. Accessed February 26, 2015.
[10] Pacific Northwest National Laboratory. *Measuring State Energy Code Compliance*. 2010. PNNL-19281. http://www.energycodes.gov/sites/default/files/documents/MeasuringStateCompliance.pdf.
[11] T. Jayaweera, H. Haeri, A. Lee, S. Bergen, C. Kan, A. Velonis, C. Gurin, M. Visser, A. Grant, and A. Buckman. *Scoping Study to Evaluate Feasibility of National Databases for EM&V Documents and Measure Savings*. State and Local Energy Efficiency Action Network and The Cadmus Group Inc. 2011. https://www4.eere.energy.gov/seeaction/system/files/documents/emvscoping_databasefeasibility.pdf.
[12] U.S. Environmental Protection Agency. *Clean Power Plan for Existing Power Plants*. http://www2.epa.gov/cleanpowerplan/clean-power-plan-existing-power-plants. Accessed February 26, 2016.
[13] Bob Slattery. *Reported Energy and Cost Savings from the DOE ESPC Program: FY 2014*. P 3. Oak Ridge National Laboratory. 2015. http://energy.gov/sites/prod/files/2015/04/f21/2014_savings_espcs.pdf.

[14] M. Fels and K. Keating. "Measurement of Energy Savings from Demand Side Management Programs in U.S. Electric Utilities." *Annual Review of Energy and the Environment* 18 (1993): 57–88. doi:10.1146/annurev.energy.18.1.57.
[15] Violette. D. and Rathburn. P. *Chapter 23: Estimating Net Savings: Common Practices The Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific Measures*. National Renewable Energy Laboratory. September 2014. http://www.nrel.gov/docs/fy14osti/62678.pdf
[16] Stern. F. *Chapter 10: Peak Demand and Time-Differentiated Energy Savings Cross-Cutting Protocols: The Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific Measures*. National Renewable Energy Laboratory. April 2013.
[17] J. Eto, R. Prahl, and J. Schlegal. *A Scoping Study on Energy-Efficiency Market Transformation by California Utility DSM Programs.* Lawrence Berkeley National Laboratory. 1996. LBNL-39058; UC-1322. http://emp.lbl.gov/sites/all/files/lbnl%20-%2039058.pdf.
[18] M. Kushler, S. Nowak, and P. Witte, *A National Survey of State Policies and Practices for the Evaluation of Ratepayer-Funded Energy Efficiency Programs*, ACEEE (American Council for an Energy-Efficient Economy), 2012, Report Number U122, 33, www.aceee.org/research-report/u122.
[19] Violette. D. and Rathburn. P. Chapter 23: Estimating Net Savings: Common Practices The Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific Measures. P 7. National Renewable Energy Laboratory. September 2014. http://www.nrel.gov/docs/fy14osti/62678.pdf
[20] Tim Woolf, Erin Malone, Lisa Schwartz, and John Shenot. *A Framework for Evaluating the Cost-Effectiveness of Demand Response*. National Forum on the National Action Plan on Demand Response: Cost-Effectiveness Working Group. 2013. https://emp.lbl.gov/sites/all/files/napdr-cost-effectiveness_0.pdf.
[21] Home Performance Coalition. *About the Resource Value Framework*. http://www.homeperformance.org/policy-research/advocacy/about-resource-value-framework. Accessed February 26. 2016
[22] National Action Plan for Energy Efficiency. Understanding Cost-effectiveness of Energy Efficiency Programs: Best Practices, Technical Methods, and Emerging Issues for Policy-Makers. Energy and Environmental Economics, Inc. and RAP (Regulatory Assistance Project), 2008. https://www.epa.gov/sites/production/files/2015-08/documents/cost-effectiveness.pdf. 2-2.
[23] Billingsley, Megan A., Ian M. Hoffman. Elizabeth Stuart, Steven R. Schiller, Charles A. Goldman, and Kristina LaCommare. *The Program Administrator Cost of Saved Energy for Utility Customer-Funded Energy Efficiency Programs*. P 54-55. Lawrence Berkeley National Laboratory. 2014. LBNL-6595E. https://emp.lbl.gov/sites/all/files/lbnl-6595e_0.pdf
[24] DNV GL and NMR. *Massachusetts Electric and Gas Program Administrators. Top-down Modeling Methods Study—Final Report*. March 31, 2015. http://ma-eeac.org/wordpress/wp-content/uploads/Top-down-Modeling-Methods-Study-Final-Report.pdf. Accessed May 6, 2016.
[25]Additional example studies/pilots on top-down evaluation include the following: Horowitz 2012; CPUC (California Public Utilities Commission) 2012; Aroonruengsawat. Auffhammer. and Sanstad 2012. 31–52; Jacobsen and Kotchen 2013. 34–49.
[26] Lawrence Berkeley National Laboratory. *Lawrence Berkeley National Lab Behavior Analytics*. http://behavioranalytics.lbl.gov. Accessed February 26, 2016.
[27] T. Eckman and M. Sylvia. "EM&V 2.0 – New Tools for Measuring Energy Efficiency Program Savings." Electric Power and Lighting. February 12, 2014. http://www.elp.com/Electric-Light-Power-Newsletter/articles/2014/02/em-v-2-0-new-tools-for-measuring-energy-efficiency-program-savings.html. Accessed February 26, 2016.

[28] Ethan A. Rogers, Edward Carley, Sagar Deo, and Frederick Grossberg. *How Information and Communications Technologies Will Change the Evaluation, Measurement, and Verification of Energy Efficiency Programs*. P vii. American Council for an Energy-Efficient Economy. 2015. Report IE1503.
[29] Miriam Goldberg, Michelle Marean, Curt Puckett, Claude Godin, Wendy Todd, Shawn Bodmann, and Kristina Kelly. *The Changing EM&V Paradigm - A Review of Key Trends and New Industry Developments. and Their Implications on Current and Future EM&V Practices*. P 53. Northeast Energy Efficiency Partnerships. Regional Evaluation. Measurement and Verification Forum. DNV GL. 2015.
[30] Ethan A. Roger, Edward Carley, Sagar Deo, and Frederick Grossberg. *How Information and Communications Technologies Will Change the Evaluation, Measurement, and Verification of Energy Efficiency Programs*. P vi. American Council for an Energy-Efficient Economy. 2015. Report IE1503.
[31] Personal communication with Tom Eckman. Northwest Power and Conservation Council (NWPPC), and Michael Li. DOE (U.S. Department of Energy). November 2015; Personal communication with Ralph Prahl (independent evaluation consultant). April 16, 2016.
[32] Personal communication with Nicole Wobus (Navigant Consulting). December 2015.
[33] Miriam Goldberg, Michelle Marean, Curt Puckett, Claude Godin, Wendy Todd, Shawn Bodmann, and Kristina Kelly. *The Changing EM&V Paradigm - A Review of Key Trends and New Industry Developments, and Their Implications on Current and Future EM&V Practices*. P 38. Northeast Energy Efficiency Partnerships. Regional Evaluation. Measurement and Verification Forum. DNV GL. 2015.
[34] L. A. Skumatz. "Recognizing All Program Benefits: Estimating the Non-Energy Benefits of PG&E's Venture Partners Pilot Program (VPP)." p 280. In *Proceedings of the 1997 Energy Evaluation Conference*. Chicago. IL. August 27–29. 1997. http://www.iepec.org/conf-docs/papers/1997PapersTOC/papers/033.pdf.
[35] L. A. Skumatz. M. S. Khawaja. and R. Krop. *Non-Energy Benefits: Status. Findings. Next Steps. and Implications for Low Income Program Analyses in California*. P 27-29. revised report. Sempra Utilities. 2010. http://www.liob.org/docs/LIEE%20Non-Energy%20Benefits%20Revised%20report.pdf.
[36] New York Public Service Commission. "Non-Energy Benefits: Values and Treatment in Cost-Effectiveness Testing—Single and Multifamily Whole-Home Energy Efficiency Programs." testimony of Lisa Skumatz. E4The Future. Inc.. September 2015. 6–7. http://e4thefuture.org/wp-content/uploads/2015/10/E4TheFuture_Skumatz_NY-PSC.pdf.
[37] A recent SEE Action report provides a more thorough discussion of DRIPE, see: SEE Action. *State Approaches to Demand Reduction Induced Price Effects: Examining How Energy Efficiency Can Lower Prices for All*. Industrial Energy Efficiency & Combined Heat and Power Working Group. December 2015. https://www4.eere.energy.gov/seeaction/system/files/documents/DRIPE-finalv3_0.pdf.
[38] M. Kushler, S. Nowak, and P. Witte. *A National Survey of State Policies and Practices for the Evaluation of Ratepayer-Funded Energy Efficiency Programs*. P 31-32. American Council for an Energy-Efficient Economy. 2012. Report Number U122. www.aceee.org/research-report/u122.
[39] Steven R. Schiller. *Energy Efficiency Program Impact Evaluation Guide*. P 7-20 to 7-24. SEE Action (State and Local Energy Efficiency Action Network). 2012. https://www4.eere.energy.gov/seeaction/publication/energy-efficiency-program-impact-evaluation-guide.
[40] U.S. Environmental Protection Agency. *Acid Rain Program.* http://www.epa.gov/airmarkets/acid-rain-program; U.S. Environmental Protection Agency. *Federal Implementation Plans: Interstate Transport of Fine Particulate Matter and Ozone and Correction of SIP Approvals. GAO-11-914R.* www.gao.gov/products/C00127; 40 CFR Parts 51. 52. 72. 78. and 97 [EPA–HQ–OAR–2009– 0491; FRL–9436–8] RIN 2060–AP50. ACTION: Final rule.
[41] See: U.S. Environmental Protection Agency. *Clean Power Plan—Technical Summary for States*., which states "2: "*Demand-side [energy efficiency] EE is an important, proven strategy that states are already widely using and that can substantially and cost-effectively lower CO_2 emissions from the power sector.*

EPA anticipates that, due to its low costs and high potential in every state, demand-side EE will be a significant component of state compliance measures under the CPP." Also see: 40 CFR Part 60. Oct. 23. 2015. 64699 at http://www.gpo.gov/fdsys/pkg/FR-2015-10-23/pdf/2015-22842.pdf.

[42] U.S. Environmental Protection Agency. *Draft Evaluation Measurement and Verification (EM&V) Guidance for Demand-Side Energy Efficiency.* P 6. Last Updated January 28, 2016. http://www.epa.gov/cleanpowerplantoolbox/draft-evaluation-measurement-and-verification-guidance-demand-side-energy. Accessed February 26, 2016.

[43] Steven R. Schiller. *Energy Efficiency Program Impact Evaluation Guide*. SEE Action (State and Local Energy Efficiency Action Network). 2012. https://www4.eere.energy.gov/seeaction/publication/energy-efficiency-program-impact-evaluation-guide.

[44] For additional discussion, see: Steven R. Schiller. *Energy Efficiency Program Impact Evaluation Guide*. P 7-8 to 7-14. SEE Action (State and Local Energy Efficiency Action Network). 2012. https://www4.eere.energy.gov/seeaction/publication/energy-efficiency-program-impact-evaluation-guide.

[45] Steven R. Schiller. *Energy Efficiency Program Impact Evaluation Guide*. P 7-1. SEE Action (State and Local Energy Efficiency Action Network). 2012. https://www4.eere.energy.gov/seeaction/publication/energy-efficiency-program-impact-evaluation-guide.

[46] A. Todd, E. Stuart, S. Schiller, and C. Goldman. *Evaluation. Measurement. and Verification (EM&V) of Residential Behavior-Based Energy Efficiency Programs: Issues and Recommendations*. p 7–8. Lawrence Berkeley National Laboratory and SEE Action (State and Local Energy Efficiency Action Network). 2012. DOE/EE-0734. https://emp.lbl.gov/sites/all/files/behavior-based-emv_0.pdf.

[47] California Assembly Bill No. 802. Energy Efficiency. AB-802. 2015 (approved October 8. 2015). https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201520160AB802.

[48] Steven R. Schiller. *Energy Efficiency Program Impact Evaluation Guide*. P 7-3. SEE Action (State and Local Energy Efficiency Action Network). 2012. https://www4.eere.energy.gov/seeaction/publication/energy-efficiency-program-impact-evaluation-guide.

[49] American National Standards Institute. *Standardization Roadmap: Energy Efficiency in the Built Environment.* P 109–152. Energy Efficiency Standardization Coordination Collaborative of ANSI. 2014. http://www.ansi.org/standards_activities/standards_boards_panels/eescc/FINAL_EESCC_ROADMAP_ONLINE.pdf.

[50] Adapted from ANSI. *Standardization Roadmap*. 109–152.

[51] Mikkel B. Rasmussen and Andreas W. Hansen. "Big Data Is Only Half the Data Marketers Need." *Harvard Business Review*. November 16. 2015. https://hbr.org/2015/11/big-data-is-only-half-the-data-marketers-need1.

[52] U.S. Department of Energy Office of Electricity Delivery and Energy Reliability. *DataGuard Energy Data Privacy Program*. https://www.smartgrid.gov/data_guard.html. Accessed February 26, 2016.

[53] For example, see: California Public Utilities Commission. *Decision Adopting Rules to Protect the Privacy and Security of the Electricity Usage Data of the Customers of Pacific Gas and Electric Company, Southern California Edison Company, and San Diego Gas & Electric Company*. California: CPUC Decision 11-07-056. July 28. 2011. http://docs.cpuc.ca.gov/PublishedDocs/WORD_PDF/FINAL_DECISION/140369.PDF.

[54] For example, see: Gregory M. Rybka, Ian M. Hoffman, Charles A. Goldman, and Lisa Schwartz. *Flexible and Consistent Reporting for Energy Efficiency Programs: Introducing a New Tool for Reporting Spending and Savings for Programs Funded by Utility Customers*. Lawrence Berkeley National Laboratory. 2015. LBNL-1003879. https://emp.lbl.gov/publications/flexible-and-consistent-reporting.

[55] Billingsley, Megan A., Ian M. Hoffman. Elizabeth Stuart, Steven R. Schiller, Charles A. Goldman, and Kristina LaCommare. *The Program Administrator Cost of Saved Energy for Utility Customer-Funded Energy Efficiency Programs*. Lawrence Berkeley National Laboratory. 2014. LBNL-6595E. https://emp.lbl.gov/sites/all/files/lbnl-6595e_0.pdf

[56] Miriam Goldberg, Michelle Marean, Curt Puckett, Claude Godin, Wendy Todd, Shawn Bodmann, and Kristina Kelly. *The Changing EM&V Paradigm - A Review of Key Trends and New Industry Developments. and Their Implications on Current and Future EM&V Practices*. P 56. Northeast Energy Efficiency Partnerships. Regional Evaluation. Measurement and Verification Forum. DNV GL. 2015.

[57] Steven R. Schiller. *Energy Efficiency Program Impact Evaluation Guide*. P 5-1. SEE Action (State and Local Energy Efficiency Action Network). 2012. https://www4.eere.energy.gov/seeaction/publication/energy-efficiency-program-impact-evaluation-guide.

[58] Ian M. Hoffman, Steven R. Schiller, Annika Todd, Megan A. Billingsley, Charles A. Goldman, and Lisa C. Schwartz. *Energy Savings Lifetimes and Persistence: Practices. Issues and Data*. Lawrence Berkeley National Laboratory. 2015. LBNL-179191. https://emp.lbl.gov/sites/all/files/lbnl-179191_0.pdf.

[59] American National Standards Institute. *Standardization Roadmap: Energy Efficiency in the Built Environment.* P 153. Energy Efficiency Standardization Coordination Collaborative of ANSI. 2014. http://www.ansi.org/standards_activities/standards_boards_panels/eescc/FINAL_EESCC_ROADMAP_ONLINE.pdf

[60] Efficiency Valuation Organization. *Certified Measurement & Verification Professional (CMVP) Program.* http://evo-world.org/en/products-services-mainmenu-en/certification-mainmenu-en. Accessed December 7, 2016.

[61] Personal communication with Steve Kromer (Treasurer, Efficiency Valuation Organization). January 29, 2016.

[62] Steven R. Schiller. *Energy Efficiency Program Impact Evaluation Guide*. P 8-9. SEE Action (State and Local Energy Efficiency Action Network). 2012. https://www4.eere.energy.gov/seeaction/publication/energy-efficiency-program-impact-evaluation-guide.

[63] 40 CFR Part 60. Carbon Pollution Emission Guidelines for Existing Stationary Sources: Electric Utility Generating Units; Final Rule. Federal Register Vol. 80. No. 205. Oct. 23. 2015. 64699. http://www.gpo.gov/fdsys/pkg/FR-2015-10-23/pdf/2015-22842.pdf.

[64] T. Jayaweera, H. Haeri, A. Lee, S. Bergen, C. Kan, A. Velonis, C. Gurin, M. Visser, A. Grant, and A. Buckman. *Scoping Study to Evaluate Feasibility of National Databases for EM&V Documents and Measure Savings*. P 12. State and Local Energy Efficiency Action Network and The Cadmus Group Inc.. 2011. https://www4.eere.energy.gov/seeaction/system/files/documents/emvscoping_databasefeasibility.pdf.

[65] U.S. Environmental Protection Agency. *Clean Power Plan for Existing Power Plants*. p 16–17. http://www2.epa.gov/cleanpowerplan/clean-power-plan-existing-power-plants. Accessed February 26, 2016.

[66] Pacific Gas and Electric Company. *Comparison of Methods for Estimating Energy Savings from Home Energy Reports*. P 2. Nexant. Inc.. 2015.

[67] Robert William Sanson-Fisher, Billie Bonevski, Lawrence W. Green, and Cate D'Este. "Limitations of the Randomized Controlled Trial in Evaluating Population-Based Health Interventions." *American Journal of Preventive Medicine* 33. no. 2 (2007): p. 156. http://dx.doi.org/10.1016/j.amepre.2007.04.007.

[68] Jessica Granderson, Phillip N. Price, David Jump, Nathan Addy, and Michael Sohn. "Automated Measurement and Verification: Performance of Public Domain Whole-Building Electric Baseline Models." *Applied Energy.* p. 144 (2015): 10–14. doi:10.1016/j.apenergy.2015.01.026. (Also published as LBNL-187596).

[69] Jessica Granderson, Samir Touzani, Claudine Custodio, Michael Sohn. Samuel Fernandes, and David Jump. *Assessment of Automated Measurement and Verification (M&V) Methods*. P 21–22. Lawrence Berkeley National Laboratory2015. LBNL-187225.

[70] U.S. Department of Energy. D*ata and Guidelines for Top-Down Energy Efficiency Analysis: Draft Workshop Report.* 2014.

[71] Chris Kramer, Emily Martin Fadrhonc, Charles Goldman, Steve Schiller, and Lisa Schwartz. *Making It Count: Understanding the Value of Regulated Energy Efficiency Financing Programs*. P 55. SEE Action (State and Local Energy Efficiency Action Network). 2015. DOE/EE-1303. https://www4.eere.energy.gov/seeaction/system/files/documents/making-it-count-final-v2.pdf.

[72] Lisa A. Skumat. *NEBs: The Latest in Results, Applications, and Best Practices for State Cost-Effectiveness Tests. Proceedings of the 2015 International Energy Program Evaluation Conference*. Long Beach. CA. August 11–13, 2015. http://www.iepec.org/wp-content/uploads/2015/papers/142.pdf.